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NASW-4003

Space Station, Engineering and Technology Development

Proceedings of the Panel on
In-Space Engineering Research
and Technology Development
May 21-22, 1985

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Space Station Engineering and Technology Development

Proceedings of the Panel on
In-Space Engineering Research
and Technology Development
May 21-22, 1985

Ad hoc Committee on Space Station Engineering
and Technology Development

Aeronautics and Space Engineering Board

Commission on Engineering and Technical Systems

National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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AERONAUTICS AND SPACE
ENGINEERING BOARD

August 2, 1985

Joseph F. Shea
Chairman, Space Station Engineering
and Technology Development Committee
Aeronautics and Space Engineering Board
Washington, D.C. 20418

Dear Dr. Shea:

I am pleased to forward the report of the proceedings of the In-Space Engineering Research and Technology Panel that met at the NASA Langley Research Center on May 21-22, 1985. The results of the meeting have been reviewed with Ray Colladay, Phil Culbertson, and members of their staffs.

The panel's task was to review the Office of Aeronautics and Space Technology's (OAST's) activities related to: identifying and implementing an in-space research and technology development (R&T) program requiring the use of the space station system and the identification of requirements for in-space support of projected R&T activity.

The review indicates that OAST is aware of the kinds of things that need to be considered and done to bring into being a real R&T program. But it is reasonably clear to me that OAST has to move very energetically and effectively to bring into being a real, funded program that represents the full spectrum of user interests, including the Department of Defense. The panel has provided comments on how this objective might be approached. This is not an easy task and will need top level management attention.

A key problem will be funding. But, there was no discussion of projected requirements or the outlook for support.

The panel believes that OAST, in the national interest, should begin to build a space R&T constituency to help define and advocate programmatic and support requirements and to build the required program. OAST has the charter for such action and should more fully exercise it.

Among other important matters that the panel believes need fuller attention are: the use of space to build a fundamental phenomena data base; establishment of representative costs for R&T in the space station to allow investment judgments to be made; and assistance to universities in building astronautics curricula and related course work material.

The panel report expands on these and other matters that it believes require early NASA management attention. One matter of special interest to OAST not addressed by the panel due to very limited data was the technical content of the program plans. This is a matter of obvious importance that must be resolved relatively early.

A point of special interest to the ASEB: NASA requested the panel to consider the establishment of a committee to address on a continuing basis OAST's in-space R&T activity. The panel concurred that such a committee would be useful, but considered the matter more appropriate for direct discussion between OAST and the ASEB.

Our deliberations and comments are intended to be constructive. It is hoped they are of value to NASA in the structuring and implementation of this important program.

Sincerely,



Richard W. Hesselbacher
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Preface

In 1984, at the request of the National Aeronautics and Space Administration (NASA), the Aeronautics and Space Engineering Board (ASEB) undertook a study of NASA's space station program. The results of this study by the ASEB's ad hoc committee on Space Station Engineering and Technology Development were published this year. NASA found the study useful and asked the ASEB to continue examination of the evolving space station program through a series of more specific studies on these subjects:

- maintainability
- research and technology in space
- solar thermodynamics research and technology
- program performance
- onboard command and control
- research and technology road maps

This report of proceedings documents the second of this series of studies, research and technology in space. The study was intended to provide NASA with comments on: activity related to definition, development, and implementation of an engineering research and technology development program requiring the space station and on the support required of the space station for this program.

The panel consisted of selected members of the committee and representatives from industry with special knowledge and experience in the science, art, and engineering pertinent to space engineering research and technology development. The panel was briefed by NASA, industry, and university representatives involved and experienced in space research and technology. NASA also identified some of the issues they wanted the panel to address. These matters were discussed by the panel and summary observations were developed.

This report of proceedings contains a brief synopsis of the presentations to the panel, notes on the discussion of the panel, and a summary of the panel's observations for NASA's consideration. For completeness, a set of presentation material is appended.

Acknowledgments

The panel expresses its appreciation to the NASA individuals involved in the definition of the program in support of and leading to an in-space engineering research and technology development program for their assistance in the review of this important area. Their presentations and active participation in related discussions assisted in putting present activity and future needs in perspective.

As with the general space station program, the in-space engineering research and technology development program is in its concept definition phase, and, as with other elements of the program, an early fix on the nature of the program will assist in the definition of the space station system design. It is in this context that the panel has made its recommendations. The recommendations deal with the nature of activities required to amplify the current process of program definition and not, at this time, with the technical substance of the program, which has not been fully defined.

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Introduction

BACKGROUND

In 1984 the ad hoc committee on Space Station Engineering and Technology Development of the Aeronautics and Space Engineering Board (ASEB) conducted a review of the National Aeronautics and Space Administration's (NASA's) space station program planning. The review addressed the initial operating configuration (IOC) of the station. The committee's study was released in February 1985. NASA factored the results of the study into its Phase B (concept and preliminary design) request for proposals issued to industry in September 1984 and awarded in April 1985.

As a result of this work, NASA asked the ASEB to reconstitute the ad hoc committee to address:

- onboard maintainability and repair
- in-space research and technology program and facility plans
- solar thermodynamic research and technology development program planning
- program performance (cost estimating, management, and cost avoidance)
- onboard versus ground-based mission control
- technology development road maps from IOC to the growth station

The objective of these new assignments is to provide NASA with advice on ways and means for improving the content, performance, and/or effectiveness of these elements of the space station program.

In response, the ASEB has reconstituted the ad hoc committee which then established panels to address each subject. The participants of the panels come from the committee, industry, and universities, providing each panel with individuals experienced in the area of special interest.

In view of NASA's interest in program definition and development, it was decided that the subjects of maintainability, program performance,

and onboard mission control would be addressed in roundtable forums focusing on concepts, system design, and organization.

It was decided that the subjects of research and technology in space, solar thermodynamic research and technology development, and technology development road maps would be addressed in workshops that focus on NASA program activity and plans.

To expedite the documentation and dissemination of the information, the deliberations of the panels are being reported as proceedings. The proceedings of the Panel on Maintainability were published in May 1985. The proceedings of the Panel on In-Space Engineering Research and Technology Development are presented in this report.

THE PANEL ON IN-SPACE ENGINEERING RESEARCH AND TECHNOLOGY DEVELOPMENT

The initial task statement for the Panel on In-Space Engineering Research and Technology Development (R&T) noted that:

NASA will outline its activity and plans for identifying and developing R&T programs to be conducted by the space station and related in-space support needs including module requirements. Included will be consideration of use of the station for R&T for other government agencies, universities, and industry.

The panel will review these activities and plans with the intent of helping to assure that an in-space R&T capability is being pursued effectively. NASA needs to resolve not only the nature of the projected R&T programs and the support and facility requirements but also its role in developing, supporting, and servicing the program. Is NASA's role the same as that for ground-based space R&T?

This statement was expanded by a set of issues identified by NASA:

The space station, with its projected capabilities and associated opportunities, is stimulating a reassessment of long-range plans throughout the space community--by planners, designers, developers, and users. The Office of Aeronautics and Space Technology (OAST) recognizes that the space station era may require new approaches to planning and implementing its technology development programs and, in a broader sense, that its role within the technology community may change. For this reason, OAST welcomes the opportunity to meet with the ASEB Space Station ad hoc Committee and begin a dialogue to identify and discuss key issues that OAST should address as it initializes its planning process to capitalize on the space station R&T opportunity. Questions that might stimulate the dialogue are:

- Will the space station R&T opportunity require new planning and budgeting strategies? Will it support a single agency in-space experiment program?
- The IOC space station is 8-10 years away--How specific can we or should we get in experiment definition recognizing that technology is a "moving" target?
- Is there a "technology" community akin to the space science community? Who are its principal members? Can it be organized and represented? How can OAST become its leader?
- What is an appropriate role for OAST in the selection of technology experiments to be conducted on the space station?
 - Consultant?
 - Advocate?
 - Broker?
 - Prioritizer?

NASA commented further that it was specifically interested in the panel's views on program content related to operational support requirements, kinds of experiments, and, where possible, specific experiments.

The proceedings reported herein cover the panel's meeting at the NASA Langley Research Center on May 21-22, 1985. The list of panel members and participants is presented on pages v-vi. The panel was briefed by NASA, industry, and university representatives; it held a general discussion of these briefings; and then, as a group, developed a set of simple statements summing up their findings. These activities are reported here. Comments are reported without attribution.

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Briefings

The graphics used for the briefings are presented in Appendix B. The following paragraphs summarize the briefings and include related panel comments where pertinent.

Research and Technology Development Overview--Paul Holloway, NASA Langley Research Center The Langley Research Center (LaRC) has the responsibility for the development and maintenance of the NASA Space Station Mission Data Base. The data base covers: science, applications, commercial, and technology development mission elements. It also notes the source of the mission data (including foreign country) and the project approval status.

The Offices of Space Station (OSS) and Space Science and Applications (OSSA) are further ahead in the process of defining space station payloads than is the Office of Aeronautics and Space Technology (OAST). This is largely attributed to the fact that OSS and OSSA have an infrastructure/constituency in place and OAST does not.

OAST is concerned about too early an involvement in supporting experiment development given changing needs and priorities associated with long program development times. For the Shuttle, OAST invested in and carried for extended periods of time experiments that were not flown because of Shuttle schedule delays and manifest priorities, as well as changing needs. OAST wants to avoid this in the space station program.

OSS needs to fix on its general/preliminary space station system support requirements by January or February 1986 so that these requirements can be factored into the preliminary design of the station. Thus, there is a need to define, at a minimum, the types of payloads and the range of support requirements (i.e., power, space, weight, and services).

OAST has the responsibility for serving as the representative of the technology and technology users community, i.e., universities,

industry, and other government agencies. However, outside of NASA's OAST field centers, OAST does not have an infrastructure the equivalent of that of OSSA. This requires attention as does the question of resources to support the development of such an infrastructure.

OAST believes that a special research and technology development (R&T) committee within the structure of the National Research Council's Aeronautics and Space Engineering Board (ASEB) would be of special value in assisting OAST in identifying program content and helping to bridge the gap in the current interfaces with industry, universities, the Department of Defense (DOD), and other government agencies.

R&T Planning Status--James Romero, NASA Headquarters The engineering research and technology development program plans identified by OAST for the mission data base have provided a gross set of space station system accommodation requirements. Most of this input comes from the NASA field centers and limited general studies by contractors. However, these representative payloads have no official status. They are not supported by budgets for the definition and development of supporting projects and plans. It is intended that this meeting assist in the initiation of a firm program definition and content process.

Space Station Utilization--William P. Raney, NASA Headquarters Space station utilization program status and user activities including technology development and demonstrations were addressed, as was the general space station schedule.

The Phase B definition effort will be completed by February 1986 to be followed by preliminary design. The final design and development (Phases C and D) effort is expected to start in late 1986. These dates may slip because of budget constraints. The present plan calls for space station operations to start in late 1992 or early 1993.

The mission modeling to date indicates the need for some technology module capability in the early space station system. There are indications that a strong case can be made for a dedicated module in the growth space station.

The mission data base calls for use of the space station itself and its operating elements--the orbital maneuvering vehicle and the space platforms in compatible and polar orbits. The NASA Johnson Space Center (JSC) will manage all of the engineering and systems integration effort for the space station. The planned budget of \$8 billion is holding for the initial operating configuration (IOC). To this, it is anticipated that foreign governments will add some \$3 billion. At this time, it appears that NASA Headquarters will be responsible for payload manifesting, in particular where foreign governments are involved.

The need for and the specifics of dedicated modules are not fully resolved. There may be some adjustment in work packages as concept work on the station and payloads progresses. However, it is reasonably clear that experiments definition and development will be kept separate from the module/accommodation definition and development that will be assigned to specific NASA centers. (The work package assignments, related contractors, and key contractor tasks are presented in Raney's charts, Appendix B.)

There is active foreign interest in the space station program. Agreements of participation have been reached on related Phase B activity with the Europeans, Canadians, and Japanese.

The European Space Agency (ESA) will be working on the design of a pressurized laboratory module. A question here is whether or not the ESA module would replace a U.S. module or represent an additional capability. Furthermore, the British are working on a platform for polar launch for ESA. At present, the system is too heavy (10,000 pounds) for the Shuttle.

The Canadians are interested in extending their work with manipulators (used on the Shuttle) to include servicing and assembly facilities.

The Japanese are interested in experiment modules. They also appear to have a serious interest in developing their own space station system, including logistics modules and orbital maneuvering vehicles.

How all of this gets sorted out, including the U.S. concern over technology transfer and the high probability of competition later, has not been resolved. This is a difficult, complex matter.

The Phase B request for proposal (RFP) identified projected user requirements (RFP, Appendix C-2). Current contractor concept efforts will provide a functional users' requirements envelope that will be factored into the space station design requirements. These requirements will result in what the users will have on the station and what they will need to design their payloads to accommodate, including crew requirements. The underlying module philosophy will follow the principles of growth and flexibility since facility design requires lead time over specific payload definition and design. Skylab experience supports the position that users should be viewed as tenants, i.e., they should provide their own support requirements and not rely on standard, built-in equipment.

Space station system user requirements have evolved from initial ideas, NASA contracted studies in 1982, and a series of workshops. A workshop in 1984, which brought in the international community, led to setting the functional requirements for the Phase B studies. The general trend has been to identify more and more needs. A major problem is to convert ideas to real, funded programs.

Since the issuance of the RFP, the Canadians have experienced budget problems, as has the ESA group. The ESA group will address infrastructures, however, the individual countries will budget for their own payloads. The Japanese have a well-organized and supported effort.

The National Oceanic and Atmospheric Administration is interested in establishing an international users group to use polar platforms for earth observations.

U.S. commercial interests have increased but funding support is not projected to be very great.

Within NASA, OAST has increased interest and activity but needs to broaden its constituency and convert ideas to real programs. OSSA has been examining the program and begun to make adjustments that reflect more realistic budget projections.

DOD has not yet taken specific steps to dialogue with NASA on space station system use. However, there is some movement on this matter. DOD has indicated that they may be ready for definitive discussions on technology experiments in summer 1985.

The trends in user-stated requirements have been: a decrease in interest in co-orbiting platforms (small for both IOC and the growth station); a large increase in polar platforms (3 for IOC and 12 for the growth station); and a large increase in support from the manned elements of the station as in Table 1.

These high user demands raise several serious problems. Is this still a want list, not supported by real program and budget commitments? The requirements do not reflect possible DOD use. Will budgets support both payload development and operations? The earth sciences and applications payloads require flight in polar orbits and on smaller platforms than those initially conceived for the space station system. Europeans and others see a need for subgravity levels of 10^{-6} to 10^{-11} , values not attainable by the inhabited space station (10^{-5} for limited periods).

TABLE 1 User Stated Requirements

	<u>IOC</u>	<u>Growth station</u>
Electric power, kW	123	375
User crew, number	14	27
Pressurized volume, M^3	169	405
Payload, dedicated STS launches/year	14	12

All of this indicates problems in two major areas: the ability to accommodate the definition and development of all of these payloads and the ability to provide the operational support from workload, transportation, and budget considerations. Shuttle limitations from payload and logistic considerations are becoming a major concern.

At this time, about 60 percent of the projected payloads reflects science and applications interest; 20 percent, engineering technology activity; and the other 20 percent, foreign, commercial, and other work. OAST represents about 10 percent of the portion of technology effort and requires a significant amount of launch and extra vehicular activity.

This adds up to the fact that, as currently documented, the stated requirements for the manned elements of the space station exceed support capability as constrained by realistic budgets and support capacity. The sum of the integrated requirements are too great to be used for design. Thus, the program will not select payloads, preclude users, or allocate station resources at this time.

For design guidance, the program has taken the following actions to provide a more realistic assessment of payload support and accommodation requirements:

- Canada, ESA, Japan--Reduce first 3 years to 80 percent, use 100 percent thereafter
- U.S. Commercial, Materials Related--Reduce first 3 years to 80 percent, use 100 percent thereafter. Do not include related NASA/OSSA work (assume support needs covered in commercial prospects)
- U.S. Commercial, General--Provide a block allocation in late 1990s
- OSSA, General Science--Reduce first 3 years to 80 percent and 50 percent thereafter (because outyear prospects have not been examined for program and budget realism)
- OSSA, Life Science--Reduce to 80 percent all years
- OAST, Technology Development--Reduce first 4 years to 10 percent and 50 percent thereafter (because of apparent lack of funding support)

The last area, OAST Technology Development, is of some concern in several respects. The program may well require upward adjustment. It does not reflect the technology development requirements of DOD or necessarily the full interests of other government agencies, universities, or industry. However, it is believed that the space station system can accommodate OAST's technology development support requirements.

The source of the budget to support the presently projected OAST workload is not evident. In addition, the projected OAST program would place heavy requirements on launch support (because of large items to be assembled) which adds to the budget question. These matters need to be addressed.

By using the above assumptions/correction factors, the major manned elements of the station can be unloaded as reflected in Table 2. These numbers are still large but considered manageable. User requirements and issues will continue to be worked on to provide a realistic capability/support envelope for station design. In the end, payload design has to take into account space station capability. All payloads will compete for space and services. The selection process has yet to be developed.

In summary:

- Current user planning does not include DOD. The department will want privacy, but it is anticipated that foreign groups will object. However, foreign and commercial users will also demand privacy. This matter will have to be addressed.
- OSSA needs to address the outyear work to assure focus and realism.
- Space station growth has not received sufficient attention; this needs work as does related budgets.
- OAST needs to broaden its representation and address the budget issue. OAST, in representing industry, should consider industry use of independent research and development funding. Possibly, the ASEB could assist in examining and advising on this matter.

OAST Program Development Strategy--John L. Anderson, NASA Headquarters

It is OAST's intention to be postured to utilize fully the space station for R&T purposes. Part of the process is to establish an effort directed at expanding the in-space R&T base through an increased OAST joint venture and collaborative activity with the R&T user community.

The objectives of the program will include: support of discipline technologies; verification/validation of predictive methods during construction, assembly, and operation of the space station system;

TABLE 2 Adjusted Requirements

	<u>IOC</u>	<u>Growth station</u>
Electric power, kW	80	375
Data to ground, MBPS	14	135
Attached payloads, number	9	13
Pressurized volume, M ³	120	330
User crew	10	20
Shuttle dedicated launches, number	4	9

utilization of the Shuttle and other in-space carriers for precursor work; and representing the broad technology user community in planning and advocacy for in-space R&T.

Implementation efforts are preliminary but are starting to serve the above goal and objectives.

OAST has used the Shuttle to extend ground-based R&T. There is a real interest in the promise of the space station system for extending the R&T base for work that is difficult or impossible to accomplish on-the-ground or in limited-duration space flight.

To help identify technology areas of future interest, a mission matrix was developed. This space-operations time matrix (through the year 2010) for different types of activity (transportation, spacecraft, and large space systems) was constructed to show types of future systems/missions, not specific missions, of interest. Transportation systems include unmanned and advanced manned transporters that could go to the moon. Spacecraft includes advanced platforms suitable for earth observations and others suitable for flights to the outer planets. Large space systems include antennas and reflector structures and structures for lunar, and later planetary, bases. Potential military interests are not reflected in the matrix.

OAST's Shuttle-based R&T reflects primarily in-house activity and interests. There has been some DOD involvement (experiments on the LDEF, long-duration exposure facility), but relatively little industry involvement in the program other than as hardware contractors. It is recognized that more direct industry and university involvement in the definition, development, and operation of experiments is desirable and would be beneficial. A practical problem is funding to stimulate and support such involvement.

It is OAST's position that in the near term it needs to: provide R&T requirements to support space station design; characterize space station R&T options; identify/advocate precursor in-space R&T; and, in the process, begin to exercise effectively a role of integrating constituency requirements for in-space R&T.

The OSS data base for engineering R&T missions has been under definition for some 2 1/2 years. However, most of the payloads identified come from an early list of potential technology experiments used to scope space station support requirements. Thus, the list does not provide appropriate time lines, priorities, and cluster requirements. Program voids are being identified and filled. Many of these, as might be expected, are interdisciplinary. The whole data base needs to be, and is being, reexamined for appropriateness in view of projected missions.

OAST has selected the following preliminary research clusters to focus its in-space R&T effort and provide the framework for its FY 1987 program and budget:

- large flexible structures
- automation and robotics
- contamination and environment effects
- fluid behavior and management

This planning process is just getting under way; this list is not necessarily complete.

OAST plans to refine its in-space R&T concepts and develop an envelope of experimental support, related in-space service, and facility requirements. These data will be used to refine the programmatic clusters and themes. However, serious questions regarding the program need to be resolved, i.e., identification of technology requirements, technical program content, and program budgets.

It was observed that these activities should involve a constituency other than NASA R&T center people, actions to gain appropriate funding, and precursor work plans. It was also noted that this planning process needs to be sustained to help build an active constituency.

The present in-space R&T program plan for FY 1987 (proposed as an augmentation to the FY 1986 budget) envisions and encompasses:

- Space structures/control--analytical studies, precursor work on the Shuttle, and use of the space station itself as a structures/controls R&T model as well as a base for independent R&T
- Contamination/environment--use of the Shuttle as a test base and continued activity with and on the space station
- Automation and robotics--use of Shuttle as a test facility with progressive increases in ability to handle complex experiments (i.e., two-arm teleoperations, robots and free-flying multiple robots with common work objective)

The end objective here is to provide a facility capability (space station) for potential investigators. A question is left open: Will NASA/OAST provide operational support for others to use such a facility as it does for wind tunnel R&T?

Another area of special interest is technology development that will allow autonomous operation of space systems, decreasing the level of ground support. Planning for this activity is just getting under way.

One area of particular technical responsibility should be characterization of the onboard and external environments associated with space station system operation and development of technologies for limiting the environmental effects.

The theme concept is being pursued by OAST as a means for organizing, budgeting, and selling the in-space engineering R&T program. This kind of presentation may be important for outside exposure, but it is the substance of the program (behind the themes) that is of fundamental importance. NASA also has a responsibility for identifying and

integrating the needs and structuring and representing the program and supporting budgets including, of course, the related NASA budget to stimulate and support the activity.

OAST is preparing a draft in-space R&T program development plan. It will be available for review in early FY 1986. This will evolve from current exploratory (field center) studies to define space station R&T thrusts and OAST's integration of the data.

OAST sees the programmatic issues as being:

- R&T needs and related operational requirements
- critical areas with the greatest leverage from in-space R&T
- criteria for evaluating and prioritizing in-space R&T
- R&T support that should be built into the space station

General commentary reflected the following:

- NASA recognizes the major elements and kinds of actions needed for program definition, development, and implementation.
- There is a need for a more definitive set of broad and specific objectives for the in-space engineering R&T program.
- What is addressed currently represents more of a budget than a program definition and support strategy.
- OAST needs to broaden the R&T input base reflecting customer/user interests and inputs and to build the related constituency for program structuring and support.
- It is recognized that the above may well require budget adjustments for program definition and support, but this is an integral part of the planning.

LaRC Space Station Organization--W. Ray Hook, NASA LaRC The LaRC Space Station Office [three divisions--Evolutionary Definition (ED), Systems Engineering and Integration (SE), and Technology (T)] has been assigned the following support roles:

- definition of the evolutionary (growth) space station (Phase A and B studies) including mission growth (ED)
- support the JSC, Level B, Systems Engineering and Integration Office (SE)
- technology transfer to Level C activities and mission model development support (T)

Specifically, the Technology Office is responsible for interfacing with the Level C centers and contractors and for these technology activities:

- develop, coordinate, and manage technology tasks and budget for Level B activity
- develop the data base
- represent all users
- develop and maintain an outreach program

- help assure space station accommodation of users
- involve customers (users) in program

The LaRC Space Station Office is developing an interface with NASA's Commercialization Office and its industry activity.

Space Station Technology Utilization Activity--Richard A. Russell, NASA LaRC The identification of technology payloads for the space station has been an iterative process (as was noted earlier). The process made use of in-house and contractor inputs and provided the input to the mission modeling and space station accommodation analyses reviewed by Dr. Raney. Table 3 summarizes this activity.

It is important to note that the missions developed in this process do not necessarily have NASA program office endorsement or support. The areas of interest include work related to materials and structures, energy conversion, propulsion, controls, human factors, and systems

TABLE 3 Space Station Payload Activity

July 1982 - May 1983

- NASA field center and industry survey
- Seventy-eight experiments identified and grouped into 31 technology development missions (TDMs)
- TDM prioritization and time-phasing
- Preliminary definition of functional requirements
- Compilation into preliminary data base

May 2-6, 1983--Mission Synthesis Workshop I, Langley Research Center

- Mission requirements updating

March 5-8, 1984--Mission Synthesis Workshop II, Hampton, Virginia

- Mission requirements updating of 21 of 31 TDMs

August 1984

- Individual experiments made TDMs to aid requirements validation activity

September 24 - October 4, 1984--Mission Synthesis Workshop III, Woods Hole, Massachusetts

- Mission requirements updating of 53 of 69 TDMs using a revised data base format
- Inclusion of international missions

operations. (Twenty-seven specific missions were identified for the panel as being of current interest.) Ten specific experiments are considered IOC priority items and are being reviewed by the JSC space station program office. These experiments are (the "●" indicates a potential mission driver):

- spacecraft material performance
- flight dynamics identification
- advanced radiator concepts
- solar thermodynamic power test facility
- long-term cryogenic fluid storage
- advanced adaptive control
- active optics technology
- microelectronics data system
- advanced automation technology
- orbital transfer vehicle technology

In addition, an effort is under way to assure that the space station will provide data to validate analyses. The disciplines of interest are structures, controls, structural dynamics, deployment and assembly, and operations. Some human factors, related to assembly, are being addressed but not the full subject.

This space effort is being reviewed with the Level C centers. Current Level C plans restrict instrumentation to that required to qualify the system and are covered in budget plans only through the first year of operation. It is proposed by space station program people that the fuller set of instrumentation be deferred until the station is essentially in its all-up IOC configuration (until about flight number 7). This matter needs to be resolved.

The present R&T program planning does not appear to reflect adequately work on human factors, life-support systems, power generation, or basic fluid physics and chemistry. It was also noted that the current experiment data base does not fully reflect R&T activity needed to advance automation and robotics.

The Space Station Office has programmed the following funds for space station system utilization: FY 1985, \$9.8 million; FY 1986, \$13.9 million; and FY 1987, \$25 million. One-half of the funds are allocated to user integration and operations. The technology development program is funded at \$1.5 million, \$1.4 million, and \$1.8 million, respectively. General user requirements (space sciences and applications and commercial accommodations) equally share the rest of the funds. Thus, OAST and OSSA will be required to support their own programs.

To help develop a realistic technology data base in FY 1985, OAST has initiated an in-house experiment requirement review. This is supported by special OSS-funded studies at Battelle and University Space Research Associates (USRA). NASA is also planning a series of industry visits to stimulate industry involvement.

The in-house review consists of a reexamination of the existing data base developed in the December 1984 LaRC workshop. The workshop identified payloads that should be flown prior to the space station (one-third), payloads that should be flown on the IOC plus 2 years (one-third), and payloads that should be flown on the growth station (one-third). The reexamination involves reevaluation, prioritization, and time-phasing. It also involves identification of voids and new experiments. These data should be available by this summer.

The Battelle study, a 6-month, \$135,000 effort, is directed at identifying R&T facility requirements. It should be completed by mid-summer and provide: an assessment of the R&T data base, space technology objectives, definition of an R&T pressurized facility and experiments (some 51), and a time-phased plan for the experiments.

The USRA study, a 9-month, \$75,000 effort, should result in a report by late fall. It is directed at forming a user group of government, industry, and universities. The activity will encompass an independent review of the existing data base, identification of gaps and new experiments, and a workshop that can be considered the initiation of a user working group.

The industry visits are under way and should be completed by this summer. Discussions have been directed at program planning and the use of company independent research and development funds. Thus far, industry interest and response has been very supportive. Plans for specific involvement are still to be developed. It is proposed to check with DOD to see if current program planning serves DOD R&T interests. The DOD's Strategic Defense Initiative group is sponsoring a university/industry meeting in June in Orlando, Florida to discuss R&T needs. LaRC will attend and review NASA's space station R&T data base and plans.

All of this activity is directed to providing input to a workshop scheduled to be held in August 1985. The workshop should produce a realistic technology data base for OAST review and action.

The program plan for FY 1986 includes new experiment accommodation studies, high-priority experiment accommodation studies, and an update of the time-phased mission model.

The new experiments examination (about 10 experiments) should be completed by early summer 1986. The NASA centers will direct this effort, which is funded at \$500,000.

The high-priority, experiment accommodation, mission driver studies (6 to 8 experiments) will be supported by selected centers and funded at \$400,000. This work is scheduled for completion by January 1986.

The mission model development will result in clustering and time-phasing the experiments and their functional support requirements. These data will be used to define the R&T facility accommodation requirements. There is an open question regarding the adequacy of

this level of analysis as the basis for dedicating a module to engineering R&T. Planned programs and real, approved, and funded programs are two different things in the view of space station program managers. To help in this regard, the LaRC R&T program people recommend that a technology user committee be formed, possibly patterned after the space station space science committee chaired for OSSA by Peter Banks of Stanford University. It is believed that this could help form a constituency and enhance program credibility and funding from within and outside NASA.

Industrial Considerations--Stanley I. Weiss, Lockheed Missiles and Space Company Discussion of the subject of industrial utilization of the space station system for engineering R&T with interested and involved colleagues at Lockheed did not result in thoughts much different from those reflected in earlier studies by the ASEB and NASA and some recent Lockheed/Arthur D. Little work. The following matters do, however, warrant comment and attention:

- expansion of general engineering knowledge
- application of the space environment for space sciences and for terrestrial uses and process modeling
- fundamental data bases
- laboratory data
- proof of concepts
- space processes and manufacturing
- space station support facility
- incentives for industry
- limits to today's planning

In summary, these observations were made:

- General knowledge of the operating environment is important to allow predictable design and performance of systems, components, and payloads.
- Space applications technology relating to and dealing with material processing is important.
- Understanding of the influences of gravity on processes is important, i.e., physical, metallurgical, and chemical. Fundamental data bases are needed. Space use as well as ground-based use of these data for terrestrial processes through a better understanding of fundamental phenomena are drivers. It should be possible to get industry support for this activity. (The Aerospace Industry Association of America is pursuing the issue of joint ventures for R&T and considering functioning as an operating entity for such ventures.)
- The types of activity and data of interest to industry are laboratory-type work related to proofs of concept, terrestrial process modeling, and space processing and manufacturing.
- It is not certain that all potential users have a clear picture of criteria for what is reasonable to do in space (versus ground-based techniques) for commercial developments, e.g., high added value, low weight, significantly high levels of productivity.

- To use space effectively and efficiently, the experience base and equipments need to be enhanced. The ability to segregate parameters and repeat work, similar to what is done in ground-based laboratories, is essential. General infrastructures/capabilities that facilitate broad use need to be identified and built.
- User incentives could help expand the user group and activity. These services should be considered: free technical advice and support, centers for commercialization, and low-cost facility rental/leasing.
- At present, limited plans are the result, in part, of limited experience with space, especially for new entrants to the field.
- Actions need to be taken to influence education. This is important since the next 10 years will produce the new space users and workers. This increases the importance and need for fundamental data bases. These data bases should include such factors as the influence of impurities and plasticity on fundamental phenomena and processes and the impact of space operations on crew behavior, functioning, and accommodation.

Potential Industrial Uses--Earl G. Cole, Rockwell International
Addressed were research applications, technology developments, service cost, and example missions.

With regard to research and technology, it is believed that most company investments will be small, on the order of \$0.5 million to \$2 million, and will focus on experiments that must be conducted in space. Some examples of small projects that can and will be funded out of company independent research and development (IRD) funds relate to special glasses, crystals and materials, flow phenomena in three-dimensional heat pipes, and small sensor systems. Rockwell has not found anything worth pursuing from pilot production considerations. An area of obvious future interest is technology development and operational demonstrations of components/systems for next generation space missions.

Rockwell has developed a small fluid-experiments apparatus (FEA), an applied research tool, for basic work requiring a free-float zone. Crew support is required to change experiments. (This is the class of equipment that could support some of the basic R&T issues addressed by Weiss.)

The most promising in-space R&T activity for the longer term appears to be that related to future space missions (e.g., lunar colonies and Mars missions) that will involve long-term, isolated operations that dictate the need for long-life systems and include the production of food.

Other obvious technology development areas of interest include the space station itself, other large structural assemblies, and large antennas and collectors/concentrators.

A major question confronting the user is the cost of in-space R&T. Private capitalization decisions depend directly on projected cost/benefit assessments. What will it cost to fly on the space station? What economic benefits will accrue? When?

NASA needs to identify at least the range of probable costs at an early date to assist in identifying and building its constituency. This should be done prior to Phase C/D. The cost should be identified in sufficient detail to allow a realistic assessment of probable costs for internal vehicular activity, external vehicular activity, power, orbital maneuvering vehicles, facility residence time and location (pressurized laboratory, attached platforms), and for other services such as preparation and transport to and from the station. There may well be a spectrum of costs for various types and classes of payloads. Of course, politics and competition will influence pricing structure.

Rockwell has developed a strawman approach to costing so that individual users can determine their investment posture (see attached charts for Cole, Appendix B). The estimated costs for transportation and services for a small, FEA class, 90-day experiment is approximately \$2 million; for a large antenna experiment, some \$20 million. The costs of the payloads themselves have to be added to these support costs.

It is estimated that the company's small experiments will represent a \$20 million program in the 1995-1999 time frame--a factor of 10 in growth from the 1980-1984 period. It is generally concluded that industry has viable applications, that the market for the space station system services will grow, and that service costs (which should be identified early) will have a strong influence on user demand.

The University Role--Laurence R. Young, Massachusetts Institute of Technology There has been an increase in sensitivity to the need to emphasize the aeronautics part of aerospace in the educational system. The Massachusetts Institute of Technology (MIT) and other universities have addressed this matter. R. F. Brodsky, in a white paper titled "The Establishment of a New Accredited Undergraduate Curriculum in Astronautical Engineering" for the American Institute of Aeronautics and Astronautics' Space Systems Technical Committee, has examined the issue and proposed a course of corrective action directed at upgrading astronautical education and certification of astronautical programs.

At MIT and other schools, the tendency has been to teach the "getting into and back from" aspects of space with little attention to what can be done and how it can be done in space. Little attention has been given to gravity-related phenomena. For the most part, people involved in space activity tend to be educated on the job and not at the university. The fact that the employers--government and industry--have not voiced concern over this situation is an anomaly.

It was noted that the Applied Physics Laboratory has focused its space-oriented graduate training into discipline, rather than system, areas. It has found this more effective since the laboratory needs discipline specialists, not system engineers.

The universities, in addition to education, play a unique role in research. They can be innovative and can undertake work of high risk requiring intensive intellectual attention, and they generally do not require large facilities.

In most aerospace engineering programs, space is an addendum to aeronautics, not an equal partner. One problem has been the content, scope, and availability of appropriate course work at both the undergraduate and graduate levels. Another problem is the lack of appropriate faculty.

It is believed that NASA can help the universities resolve these matters through support of predoctoral programs that include, integrally, the development of curriculum material that can become instructional material. This could be realized through the establishment of a 1-year prestigious NASA space engineering fellowship (teaching assistant) program specifically for: space engineering course curricula and the definition and development of lecture notes for the teaching of new space engineering courses. As part of the fellowship program, spending one summer at a NASA center engaged in research using unique facilities would be encouraged or required to gain experience.

To encourage students and faculty to enter such a program, consideration could be given to:

- offering forgiveable loans (say for 2 years) to encourage staying in the space field
- providing for the teaching of 2-week summer courses after the 2-year program to disseminate the new material developed in the program and to attract students to the space field
- providing funds for faculty to develop new space engineering course notes for space engineering curriculum development

It was estimated that it would take about \$20,000 per student (possibly up to \$3 million per year for 10 institutions) for such a program to have an impact.

It was noted that NASA currently supports a graduate student program, which is described in the pamphlet "Graduate Student Researchers Program, 1985" by the NASA Office of External Relations in Washington, D.C. The program is directed at increasing the number of "trained scientists and engineers in . . . space technology to meet the continuing needs of the national aerospace effort." The program supports about 80 graduate students in thesis research on NASA-identified work related to NASA programs. These graduate students have access to unique NASA equipment and facilities and can interact with NASA research personnel.

The panel was in general agreement with the summary recommendation of the presentation:

- NASA is encouraged to establish a university predoctoral traineeship program in space engineering with emphasis on curriculum and teaching material development. As part of the program, ties to NASA centers should be encouraged.

3

Discussion

This chapter reflects individual comments, not necessarily the consensus, from the discussion at the meeting. The short statements are organized, without attribution, according to planning and budgeting, technical content, and the role of the Office of Aeronautics and Space Technology (OAST).

PLANNING AND BUDGETING

The statements that follow relate to program formulation, planning, and the development of related budget estimates for program implementation.

- The statements of objectives, strategy, and issues for the in-space engineering research and technology development (R&T) program do not reflect simply and clearly the thrust, approach to program definition, and issues.
- The OAST objective, "To establish a program leading to broad utilization of the space station . . .," does not draw attention to the fact that the program is directed at building the technical capability to utilize space more fully for scientific and applied purposes. "Utilization of the space station" is just part of the means.

Part of the strategy for accomplishing the objective of building technical capability is to involve others (universities, industry, and other government agencies) in the process of identifying and implementing programs.

Other points that NASA should factor into a statement of background, objectives, and strategy are the following:

- Advances in space engineering technology development will be required over an extended period of time.
- In-space R&T is an integral/required part of the program.
- NASA will have the capability and be in a unique position to establish facilities in space to help the nation capitalize on this capability.

- NASA/OAST has a responsibility and a charter to provide the required leadership to develop the facilities and technology program.*
- The original data base is being reworked and plans are in process to involve the space engineering R&T community more heavily in the idea-generating and review process. The basis for the plan appears to be things that could be done not things that need to be done. Thus, it is not clear that this program development process will be successful without starting with realistic, probable missions and related technology questions and issues that need to be resolved.
- The in-house and contracted R&T study effort does not build needed constituency and advocacy nor broaden the idea data base. It does not address the critical problem of funding. (On this latter point, program costs were not addressed in the NASA presentations, only near-term study budgets.)
- Industry should be stimulated to invest its independent research and development (IR&D) funds in in-space R&T through independent, joint, and/or integrated programs within industry and/or with NASA. Programs should consider ground-based and Shuttle flight work, not just use of the space station. NASA funding (seed money) and aggressive R&T program support would be keys to such stimulation.**
- NASA seed money will be followed by IR&D funds and further industry investment. Thus, it is important for NASA to act as a catalyst. The same is true for the universities.
- It is not apparent that NASA has fully exploited the opportunities to use space to accelerate technology development. It is not clear if this is a mind-set, flight opportunity, and/or funding constraint problem.
- OAST's small budget is a matter of concern. It may be appropriate for generic ground-based and limited space flight work but does not appear to be adequate for this new thrust. Requirements need to be identified and a strategy and approach developed to gain a more appropriate budget posture for the full spectrum of activity, including in-space research and technology development.

*Related material provided by D. P. Hearth, Appendix C: (a) Briefing charts from NASA study of "NASA's Support of the Space Industry (and DOD)," February 24, 1984; (b) James M. Beggs, NASA Administrator, letter to NASA R&T management, April 3, 1984; and (c) "Study of U.S. Industry Use of NASA In-Space Facilities for Technology Experiments," December 1984.

** Related commentary: "A Current Perspective on Space Commercialization," Aerospace Industries Association of America, Inc., April 1985.

- A matter related to payload definition and development is in-space facility definition and outfitting and the development of related program staff to support the effort.
- The definition and development of a funded program (with inputs from the user community, universities, and NASA) is key to competing with other users of in-space facilities and flight time.
- In aeronautics, NASA brings unique R&T capability to the table. In space, there is an opportunity to develop and provide a similar unique capability. This needs to be approached boldly, using the constituency to help define future program and support needs that include schedules and resources.
- At present, OAST's space R&T effort is supported by a budget of about \$145 million. About 40 to 50 percent is allocated for direct charges; about 30 percent goes primarily for contracted support of NASA programs. A small amount goes to universities; again much of it is focused on direct support of NASA activity. Thought should be given to providing more opportunities for new research and technology developments.
- Regarding education, there is a need to involve more students in real programs. This should be more fully addressed by NASA and industry with the universities.

TECHNICAL CONTENT

The statements that follow relate to the technical aspects of the program.

- The materials presented dealt with the subject of the meeting at a high level. There was little technical substance, so it was not possible to comment on and assess technical content.
- Because the themes identified by OAST are not complete in program coverage nor in the detail, it is not possible to judge relative priorities.
- There is a need to go to the technology user community to identify and become sensitized to considerations and constraints that affect the use of space for research, technology development, and commercial applications, i.e., low-costs, high technical confidence, high productivity, and unique products. User involvement is needed to help ensure program breadth and utility and to provide constituency and advocacy.
- It does not appear that in-space flight for R&T has been fully recognized as a needed part of the R&T program. This may be a mind-set problem affecting R&T priorities in OAST and the NASA field centers. Although OAST has a flight projects group, a separate activity may be required to pursue the building of this program.

- Projected large projects do not reflect an attempt to extract the technical issues and tailor the ground and space flight activity to resolve them without going to large experiments that are expensive in time and resources.
- Constituency, as well as funding, is an important ingredient for the establishment of a sound, useful space engineering research and technology development program. NASA management needs to act on both constituent and technology program development.
- A relationship that needs to be changed: the space industry looks to NASA as a source of funds, not technology; NASA looks at industry as a contractor, not as a user of technology.
- OAST's objective should be to identify technology issues regarding space utilization and to help define, develop, and implement R&T programs (ground and flight) to resolve the issues and develop the technology data base. Some related issues are the following:
 - lack of an effective outside constituency and related support
 - slow definition and development of the program
 - lack of an adequate budget to support appropriate engineering R&T activityActions that can be taken (and may be under way) are the following:
 - more fully using space flight opportunities for R&T
 - start up a competitive "program opportunity notice" activity to stimulate universities and industry
 - develop outside principal investigator teams and consider peer review for selection of projects, including NASA projected activity
 - fund activity through the discipline groups at the centers to build relationships between the NASA staff and principal investigators
 - collect research and technology data on the space station system during assembly and growth (this should be given high priority)
 - take positive steps to identify and implement a space engineering research and technology development program plan
 - follow through on the idea of forming an analog of the space station committee of the Office of Space Science and Applications (OSSA) to assist in the definition, review, and development of OAST's program, a continuing process. The program should cover the engineering technology requirements of the science and applications programs.
 - include work on longer term missions, beyond the initial and growth space station system
 - pursue both fundamental and applied R&T

ROLE OF OAST

The following comments relate to the role OAST should have in the definition, development, and implementation of in-space engineering R&T.

- The nation is in the process of building a space facility for nationalistic reasons. The space science and applications communities are providing their requirements to the system designers through the use of a network of constituents developed over a period of some 25 years. A space engineering constituency network has not evolved or been organized and used to generate and support engineering technology needs. This should be done.
- It is a fact that, in most instances, technology development activity is promulgated and supported within projects and not by OAST. The question is whether or not this is the appropriate way to develop technology, i.e., tie technology development close to the need, user, and project. This appears to be the high-risk, expensive way to support projects and leads to conservative technology development and application. This has been a long-standing problem and issue that should be addressed again.
- Most of the principal investigators are NASA employees. NASA is interested in expanding its principal investigator base and, through this, the content of the program.

An idea NASA could consider to help expand the principal investigator base is to make use of NASA's announcements of opportunities for competitive space R&T work.

The program could start at about the \$10 million level split evenly between universities and industry. Initially, this effort would support small experiments under the management of NASA center discipline groups. Future work could be expected to grow in complexity, size, and funding.

To give the effort a quick start and show OAST's serious intention, the initial funding should come from the current budget.

- The theme idea is a way to consolidate and display the projected program. The themes are not comprehensive enough to reflect important technology content. Significant missing themes, at present, are electric power systems and crew-related factors. There may be others.
In building the themes, OAST should be careful not to confuse budget packaging with technical program development.
- R&T studies to date do not appear to support the need for a dedicated facility (module) for the initial space station. Another observation is that the R&T program base needs to be broadened to provide better insight to future engineering R&T needs and user interests. A dedicated in-space R&T laboratory could be expected to evolve and become part of the growth station. OAST needs to move expeditiously to develop an in-space R&T program.
- The panel discussed the material contained in Appendix D, related to an OSSA task force on scientific uses of the space station, in considering OAST's request to form a committee of the Aeronautics and Space Engineering Board (ASEB) to serve OAST on the subject of in-space R&T. It was concluded that:

- The OSSA task force has a constituency and credibility from past related activity.
- The task force charter could be adapted for OAST.
- The panel supports the concept of a committee for in-space engineering research and technology development, but it believes the issue of ASEB involvement should be taken up directly with the ASEB and that OAST should develop a statement of objectives to focus deliberation.

4

Summary Observations

Following the presentations and general discussion, the panel developed its observations. These observations are presented in this chapter in the form of simple summaries addressing premises, objectives, issues, and strategies. Also presented in this chapter are responses to the Office of Aeronautics and Space Technology's (OAST's) questions to the panel.

PREMISES

- Advances in technology will continue to be required for more effective operations in and for the use of space.
- Space technology research and development requires experiments conducted in space.
- NASA has the national responsibility for conducting and stimulating space technology research and development and for providing support in space for such activity.
- NASA has and will have unique national facilities for space technology experiments.
- OAST should provide leadership for the definition and development of required experiments to support the engineering technology needs of the user industry, other government agencies, and universities, as well as its own laboratories for all in-space engineering R&T.

OBJECTIVES

- Expand the engineering R&T data base to enhance the operations in and utilization of space.
- Define, develop, and implement appropriate space engineering and technology development programs, and, as required, develop facilities for in-space engineering R&T.

ISSUES

- There is a lack of an outside engineering R&T users constituency comprised of universities, industry, and other government agencies.
- Current NASA culture does not appear to recognize fully the value of in-space R&T development. (This is reflected in the lack of R&T use of current flight hardware.)
- The funds for in-space R&T program development and implementation are inadequate.

STRATEGIES

Immediate Activity

- Allocate \$10 million per year, starting in FY 1986, from the OAST space budget (growing as appropriate in later years) to develop a network of academic, industry, and other government agency principal investigators for in-space engineering R&T activity. The \$10 million should be equally divided between academia (fully funded) and industry (matching funds). Academia funding should be a minimum of about \$100,000 per task.
- Include development of space engineering curriculum and related teaching materials in the university program effort.
- Establish a competitive process using peer review procedures to select candidate experiments.
- Distribute funds to principal investigators through discipline organizations in the NASA/OAST field center discipline offices.
- Act on the NASA management directive to define and implement a program. Include development and use of a constituency.
- Include in the program the collection of research quality data on the space station during assembly and initial operation. Make timely use of the outside community. Give the program high priority.
- Act on the establishment of an analog of the OSSA's space station space sciences committee. The OAST committee would be established to review and advise on program planning and implementation and to examine progress periodically against plans.

Future Activity

- OAST needs to continue its effort with user groups to determine the scope and the nature of future in-space facilities required to support the kinds of engineering R&T anticipated. The specifica-

tions, like those for a wind tunnel, need only address projected general accommodations and support needs. It should be assumed that special R&T services will be provided by the users.

- OAST, in concert with the NASA research centers and outside groups, should develop a long-range plan for in-space technology flight experiments.
- Future plans should include attention to fundamental as well as applied engineering research.
- Flight opportunities for engineering research data should be continually studied, evaluated, and implemented by OAST and its constituency and results published.
- Space flight experiments should be obtained competitively from the principal investigator community (universities, industry, and other government agencies as well as from NASA centers).

RESPONSES TO OAST'S QUESTIONS

In amplifying the panel's task statement, OAST asked the following questions:

- Are new planning and budgeting strategies required?
- Will (should) a single agency support the in-space R&T program?
- How specific should the R&T definition work be? The space station operational flight is some 8 to 10 years away.
- Is there a technology community akin to the "science community"? How can OAST organize and represent this community?
- What is OAST's role in the selection and conduct of R&T in the space station system?
- What specific and general comments are there regarding the present technical content of the program?

These questions were not addressed directly by the panel at the meeting. However, the panel's observations and comments provide the basis for the following responses that have been reviewed individually by the members of the panel.

New planning and budgeting strategies are required. The planning needs to involve the user community (industry, government, and universities) more actively as well as the NASA centers. An integral part of this planning involves the development of the appropriate infrastructure of users for payload and budget definition. The plans need to identify budgets, sources, and the actions required to gain budget support. The planning needs to cover current approved program needs, high probability extensions, and new starts as well as new unassociated ideas and concepts.

An in-space R&T program developed and managed by a single agency (not including facilities) is not believed to be appropriate. A

single agency cannot serve, nor would it be supported by, the civil and defense interests of the nation. The idea of a single operating and support agency (much like NASA for unique aeronautics R&T facilities) does have merit. It is believed that an activity that centralized facility planning and development and provided consultation and support to the user community would be supported by program constituents.

Whether the Space Station Office or OAST "under contract" to the Space Station Office carries this responsibility is an issue.

The degree of specificity of support for R&T activity, including time phasing cannot be generalized. Specificity, of course, is a function of the particular R&T program and its complexity, including precursor analytical, ground-based, and flight work to prepare for space station flight. It is clear that major investments in precursor work and space station flight hardware should not be made unless there is assurance of a position on the payload/operations manifest. Each situation will have to be judged on its own merits and levels of uncertainty.

The technology community akin to the science and applications community can be organized and represented by OAST. The technology community consists of space users and R&T contributors, i.e., industry, universities, other government agencies, and the NASA centers. Through individual dialogue, in-house and contracted studies, and joint planning efforts, OAST can and should serve the role of integrating and developing representative plans and programs. These can be reviewed and critiqued by a group of reasonably high-level representatives from the constituent groups constituted for this purpose. The results of these reviews would be used by the constituents to guide the development of their programs. OAST could use these data to guide its own R&T program and to define and develop appropriate national facilities, including the space station, to support projected needs.

OAST's role in the selection and conduct of R&T in the space station should parallel that of work in aeronautical facilities. Approval and support (including financial) should be a function of the importance of the proposed work and public availability of the data. If the proposed work is proprietary or for DOD, it should be treated as is related aeronautical work where merit, available time, payment, DOD request, and data availability are some of the factors considered in selection and support.

Program technical content cannot be judged because of the limited detail present to the panel. In general, the right kinds of things are being proposed, but examining the themes indicates they are not complete. In the case of very large systems, there is some concern that possibly too little thought has been given to identifying key technology issues and to looking for simple ways to resolve the issues without going to large complex structural and system test articles.

5

Closing Comments

Although NASA has been examining engineering technology missions for space stations through in-house and contracted studies and workshops that included industry and foreign inputs, a firm funded program has not evolved. This is due, in part, to the fact that the thrust of this effort has been directed at scoping onboard space station engineering research and technology (R&T) accommodation requirements and not necessarily at defining a definitive in-space R&T program.

These requirements are being integrated with the projected requirements of other users (commercial, space sciences and applications, foreign governments, and potentially DOD) and used by the space station program office to develop preliminary R&T support specification for the initial and growth space station.

At this point, the Office of Space Station (OSS) has assigned a low rating to the probability that the Office of Aeronautics and Space Technology (OAST) and the constituency represented in the planning will be able to fund the projected space engineering research and technology development program. Although OSS notes that the system requirements identified by other users cover the OAST R&T so that most of the missions identified could be accommodated, of concern is the fact that there is little confidence that the program will be funded and produce payloads. It is of paramount importance that a meaningful R&T program be identified and supported. The work on the Shuttle represents a start that should be built on. The space station itself is part of the next set of R&T targets.

In past space flight developments, relatively little attention was paid to the spacecraft as a research and technology development subject. The space station system represents too great an R&T opportunity for all technology disciplines to allow it to slip away, as has happened in other space flight developments. The space station system should be treated as a research airplane. Design issues, instrumentation, and test protocol should be identified and integrated into the design, development, and early operational activity. Now

will be the least expensive and most effective time to address and implement such a program.

OAST needs to involve the community of users, including the universities, in the broad R&T effort. This might best be done by OAST taking the lead in the development of a strawman program plan, starting with technical issues stemming from realistic space flight system projections. This plan could be the basis for an indepth technical workshop with outside and inside experts to review, advise, and refine the gross plans. To make the plan real, schedules, budgets, and budget sources should be identified and appropriate levels of approval obtained. It would be most desirable to complete this realistic scoping effort before the second part of the space station Phase B (preliminary design) study gets under way early next year.

However it is done, OAST needs to identify for itself, and the space station program, the engineering technology research and development program (in terms of needs, need for in-space work, and related activity) that is to be funded. The timing here is critical in terms of identifying the probable real program in time to affect the preliminary design part of Phase B. Input from the user community, including DOD, should be pursued.

If properly exercised, this activity will serve to strengthen OAST's efforts to build the constituency that it needs to represent. However, other actions are warranted. These actions involve seeding space engineering research and technology development within the universities and industry; involving other government agencies and serving their interests; and establishing a review, assessment, and advisory group that follows program definition, development, and implementation on a continuing basis.

Other matters that should be given attention include: more emphasis on basic R&T to build the understanding of the effects of space flight and operations environment on basic phenomena; estimation of costs for the conduct of in-space R&T so that options can be assessed and investment decisions made; promulgation of university activity to support the development of astronautics courses and related instructional material; and assistance in the broadening of the R&T base through the tool of announcements of in-space R&T opportunities.

The panel is appreciative of the support provided by NASA personnel and their active participation in the meeting. Panel members expressed a continuing interest in the development of the program and a willingness to meet at a later date to review and assess progress.

APPENDIX A

Meeting Agenda

SPACE STATION ENGINEERING AND TECHNOLOGY DEVELOPMENT
Panel on R&T in Space MeetingAGENDA

May 21-22, 1985
NASA Langley Research Center
Hampton, Virginia

Tuesday, May 21

R&T Overview and Welcome	P. Holloway, LaRC
Introduction Objectives Approach	R. Hesselbacher, Chairman
Charge to Panel, OAST Overview	J. Romero, NASA
Review of NASA Activities Space Station Utilization OAST Planning Technology Utilization	NASA Representatives W. Raney, HQ J. Anderson, HQ R. Hook, LaRC R. Russell, LaRC
Industry Views Lockheed Rockwell	S. Weiss E. Cole
University Views MIT	L. Young
Discussion	Panel
<u>Wednesday, May 22</u>	
Discussion (cont.)	Panel
Drafting of Observations	Panel

APPENDIX B

Briefing Graphics

Research and Technology Development Overview	37
P. Holloway, NASA Langley Research Center	
Research and Technology Development Planning Status. . .	No graphics
J. Romero, NASA Headquarters	
Space Station Utilization.	41
W. Raney, NASA Headquarters	
OAST Program Development Strategy.	65
J. Anderson, NASA Headquarters	
LaRC Space Station Organization.	93
R. Hook, NASA Langley Research Center	
Space Station Technology Utilization Activity.	95
R. Russell, NASA Langley Research Center	
Industrial Considerations.	131
S. Weiss, Lockheed Missiles and Space Co.	
Potential Industrial Uses.	133
E. Cole, Rockwell International	
The University Role.	153
L. Young, MIT	

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TECHNOLOGY PAYLOADS

WHY NOW ?

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WHAT IS NEEDED ?

- PROGRAM CONTENT
- FACILITY REQUIREMENTS
- EASY ASSESS TO "SYSTEM"
 - OA ST ROLE
 - LaRC ROLE
 - OSS ROLE
- "R&T" COMMITTEE

REQUEST

- ESTABLISH COMMITTEE
- RECOMMEND PROGRAM CONTENT
- RECOMMEND APPROACH TO DOD/
INDUSTRY/UNIVERSITY



SPACE STATION UTILIZATION
PRESENTATION TO:

**ASEB PANEL ON R & T
IN SPACE**

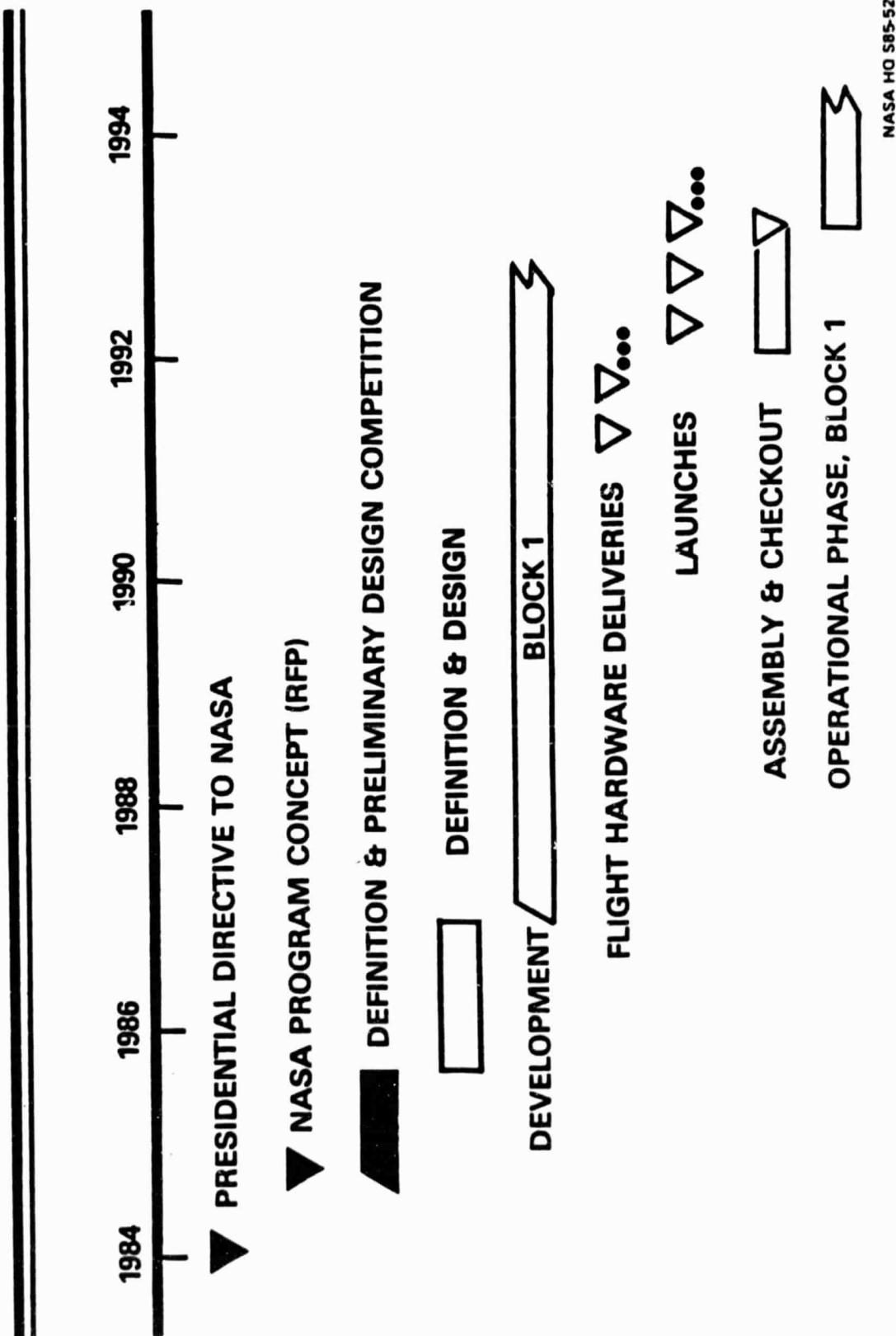
DR. WILLIAM P. RANEY
Director, Utilization & Performance
Requirements Division
Office of Space Station
May 21, 1985

SPACE STATION UTILIZATION

- PROGRAM STATUS
- USER ACTIVITIES
- TECHNOLOGY DEVELOPMENT AND DEMONSTRATION

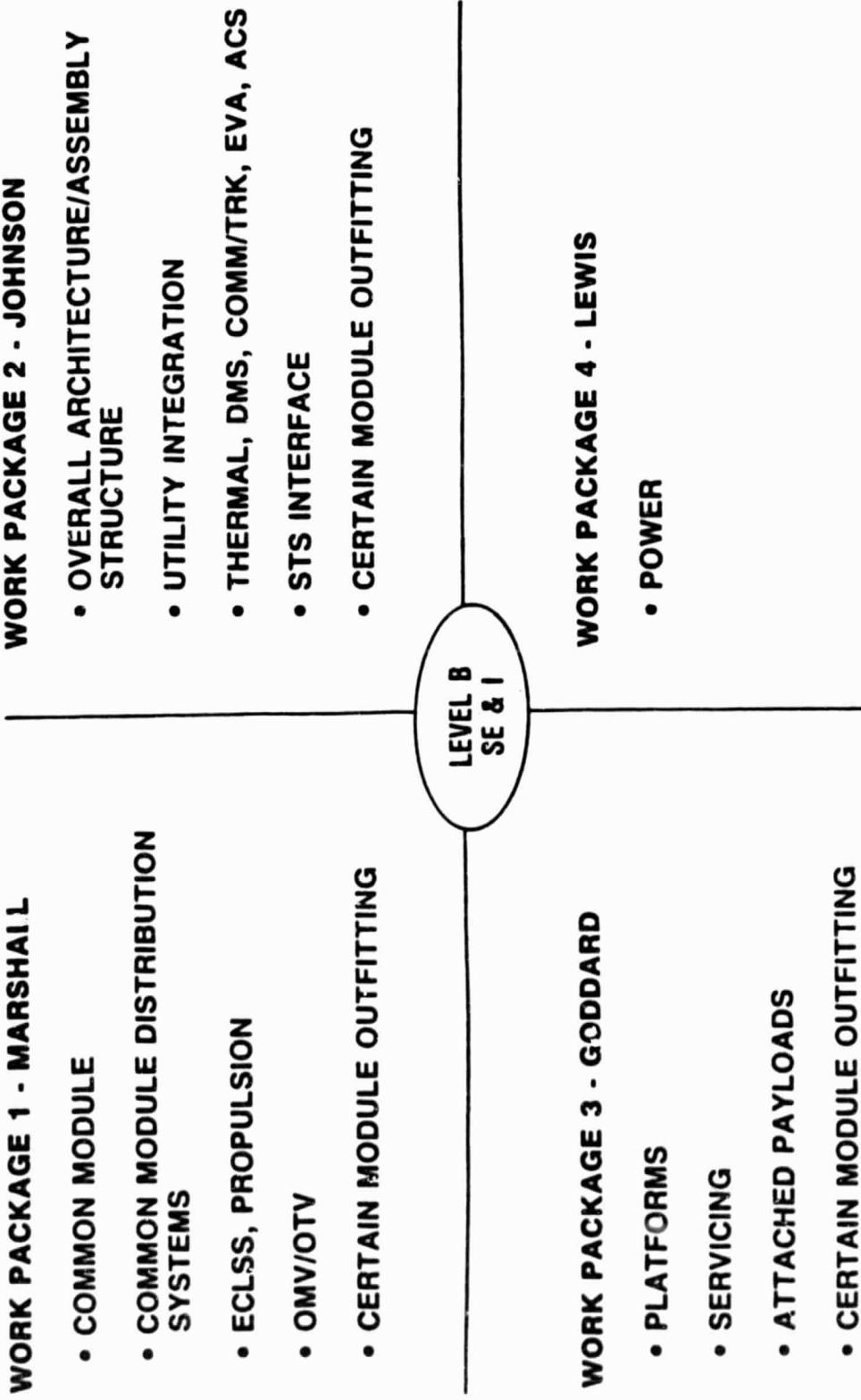
SPACE STATION PROGRAM MILESTONES

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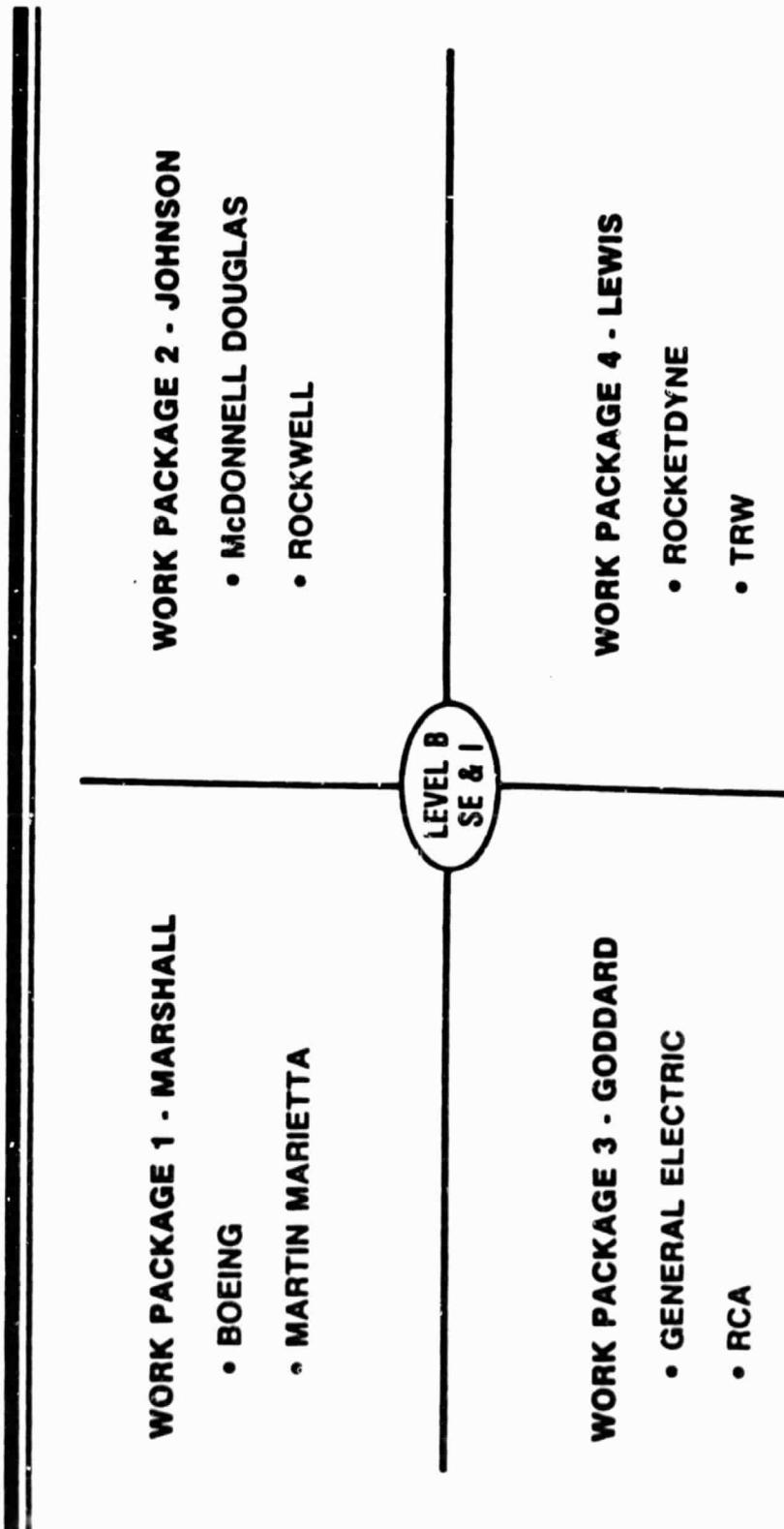


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SPACE STATION PROGRAM
WORK PACKAGE STRUCTURE
FOR DEFINITION AND PRELIMINARY DESIGN RFP



SPACE STATION PROGRAM
WORK PACKAGE STRUCTURE
FOR DEFINITION AND PRELIMINARY DESIGN RFP
PRIME CONTRACTORS



SPACE STATION PROGRAM DEFINITION AND PRELIMINARY DESIGN PROCUREMENT

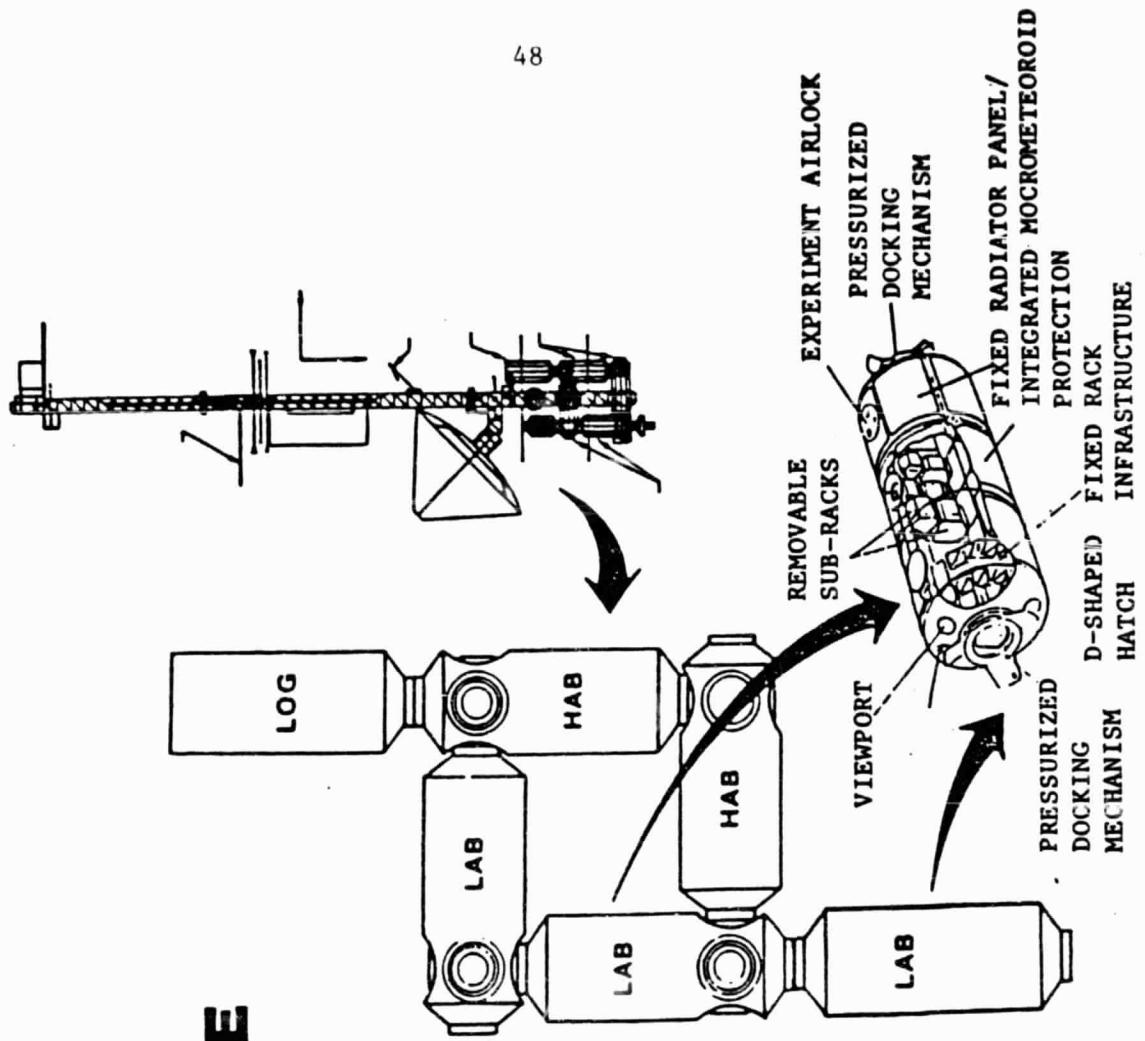
KEY TASKS REQUIRED OF CONTRACTORS

- Systems engineering and integration
 - within work packages
 - in support of Level B
- Preliminary design
- Advanced development
- Customer integration
- Operations planning
- Programmatic
- SRM + QA
- Study management

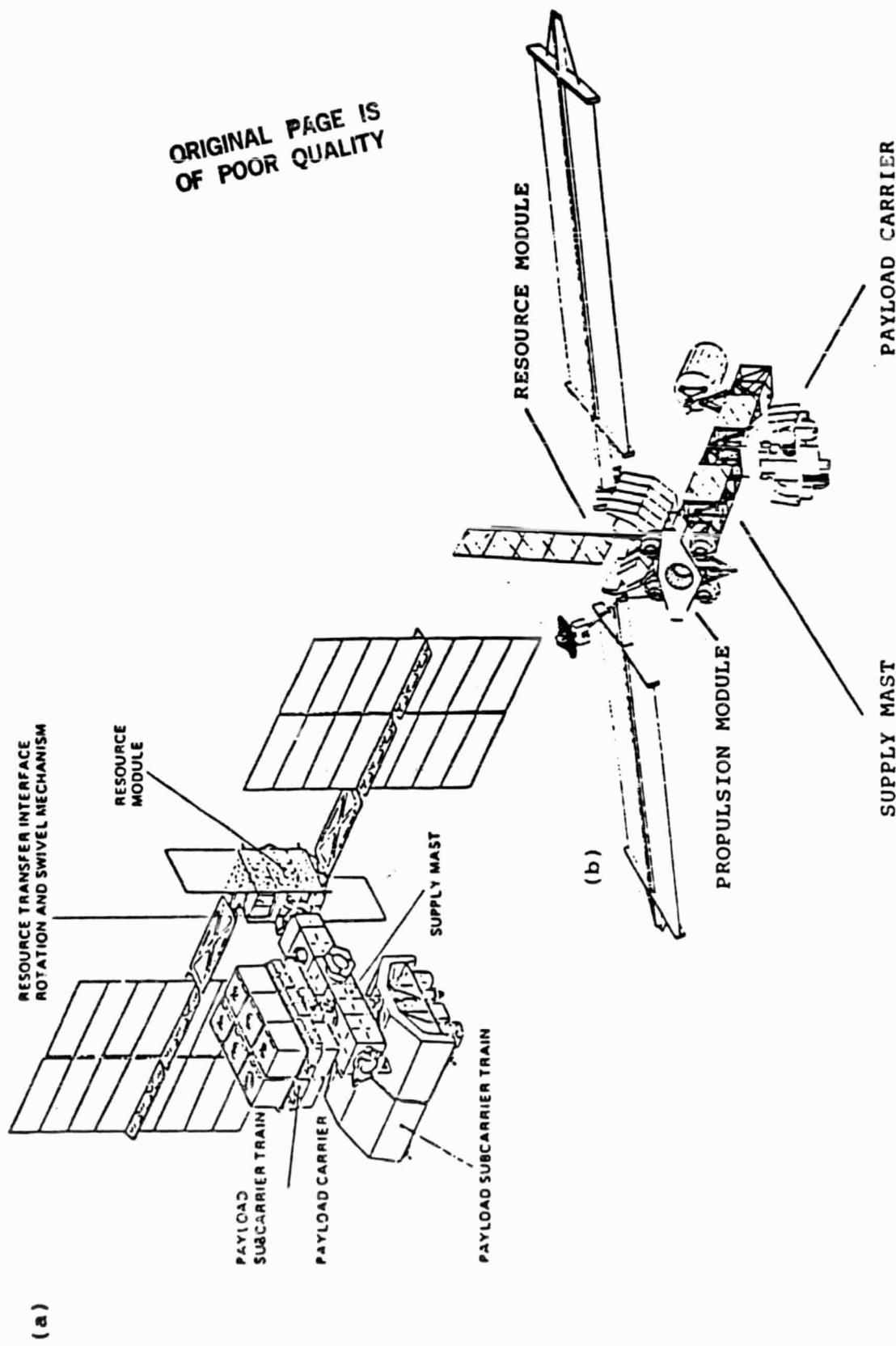
INTERNATIONAL INTEREST IN U.S. SPACE STATION PROGRAM

- Substantial foreign interest exists in NASA's space station program
- This interest derives in part from:
 - existing contributions to Shuttle
 - past and present cooperative activities with NASA
 - recognition that a U.S. space station is the next large development program
 - maturity of foreign aerospace industries
 - Spacelab development is winding down
- In the 1984 State of the Union message, President Reagan invited U.S. allies and friends to participate in the space station program
- In the spring of 1984 NASA Administrator visited Europe, Canada and Japan for high-level discussions on international participation in the station
- Space Station was discussed at 1984 London Economic Summit and at the 1985 Economic Summit in Bonn
- Space Station partners must be sensitive to U.S. concerns about technology transfer, exporting jobs and efficient management
- ESA, Canada and Japan have signed Memoranda of Understanding (MOU) with NASA that provide framework of cooperation on space station during Phase B

ESA PRESSURIZED MODULE REFERENCE CONFIGURATIONS



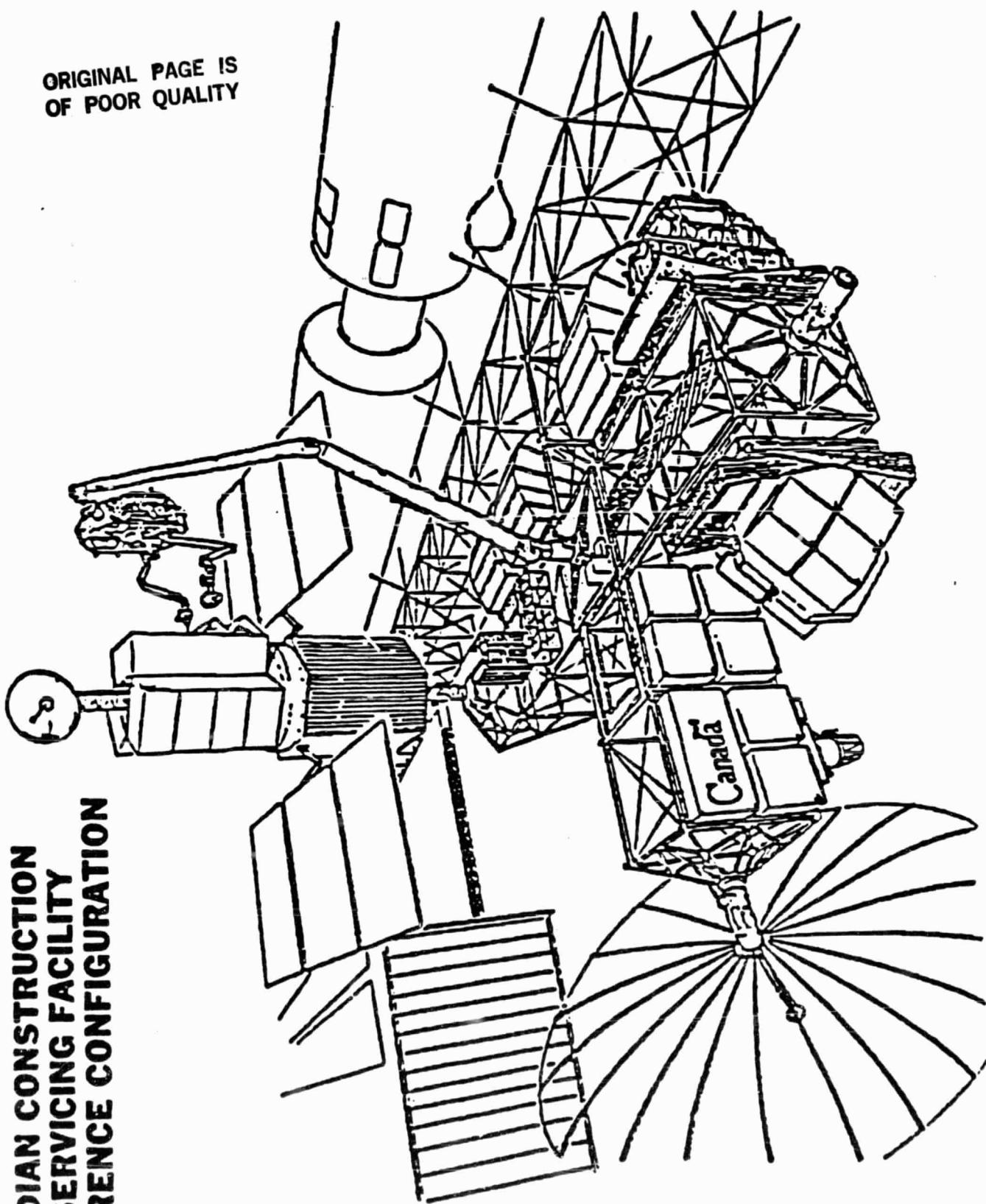
ESA PAYLOAD CARRIER AND RESOURCE MODULE REFERENCE CONFIGURATIONS



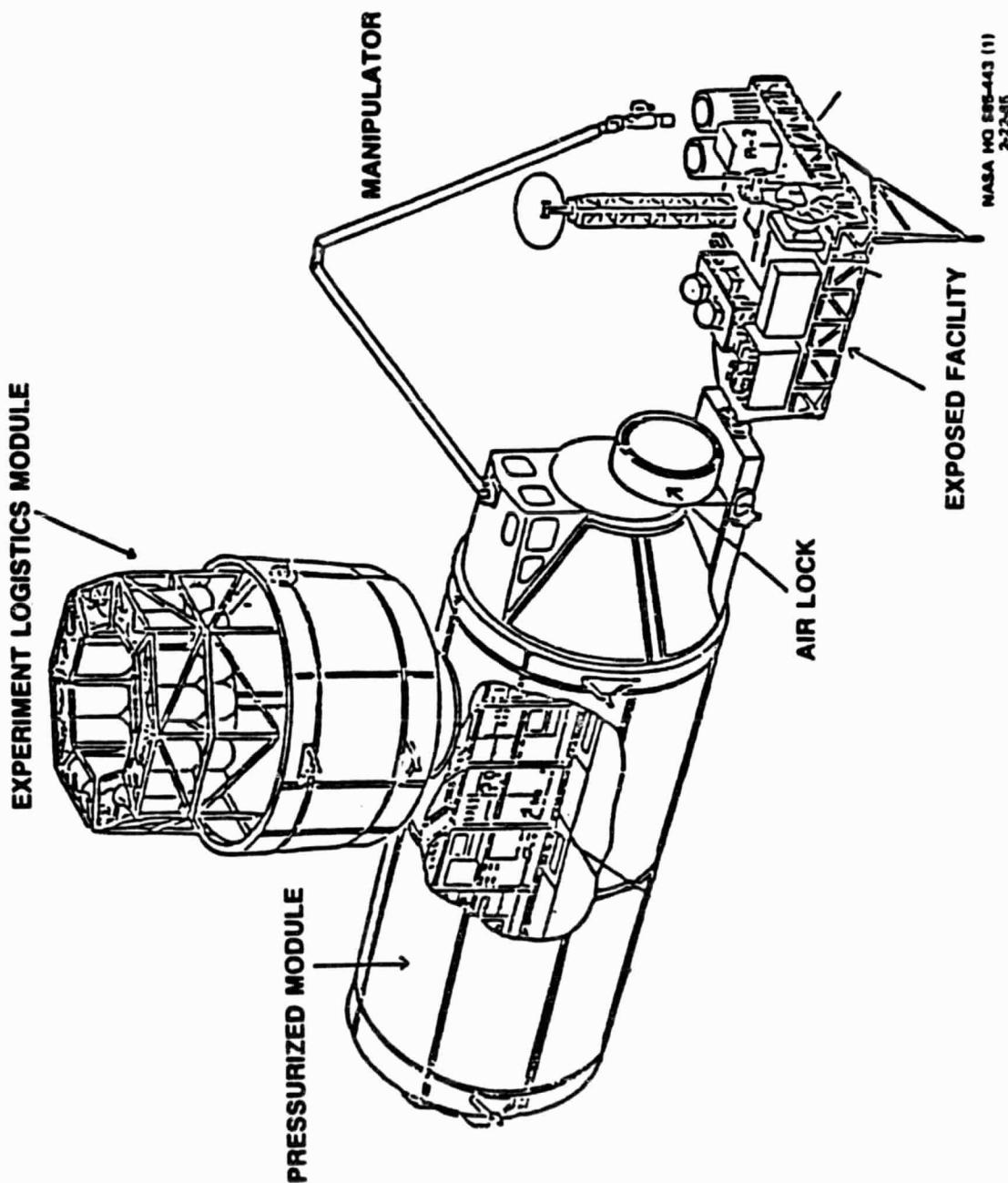
**CANADIAN CONSTRUCTION
AND SERVICING FACILITY
REFERENCE CONFIGURATION**

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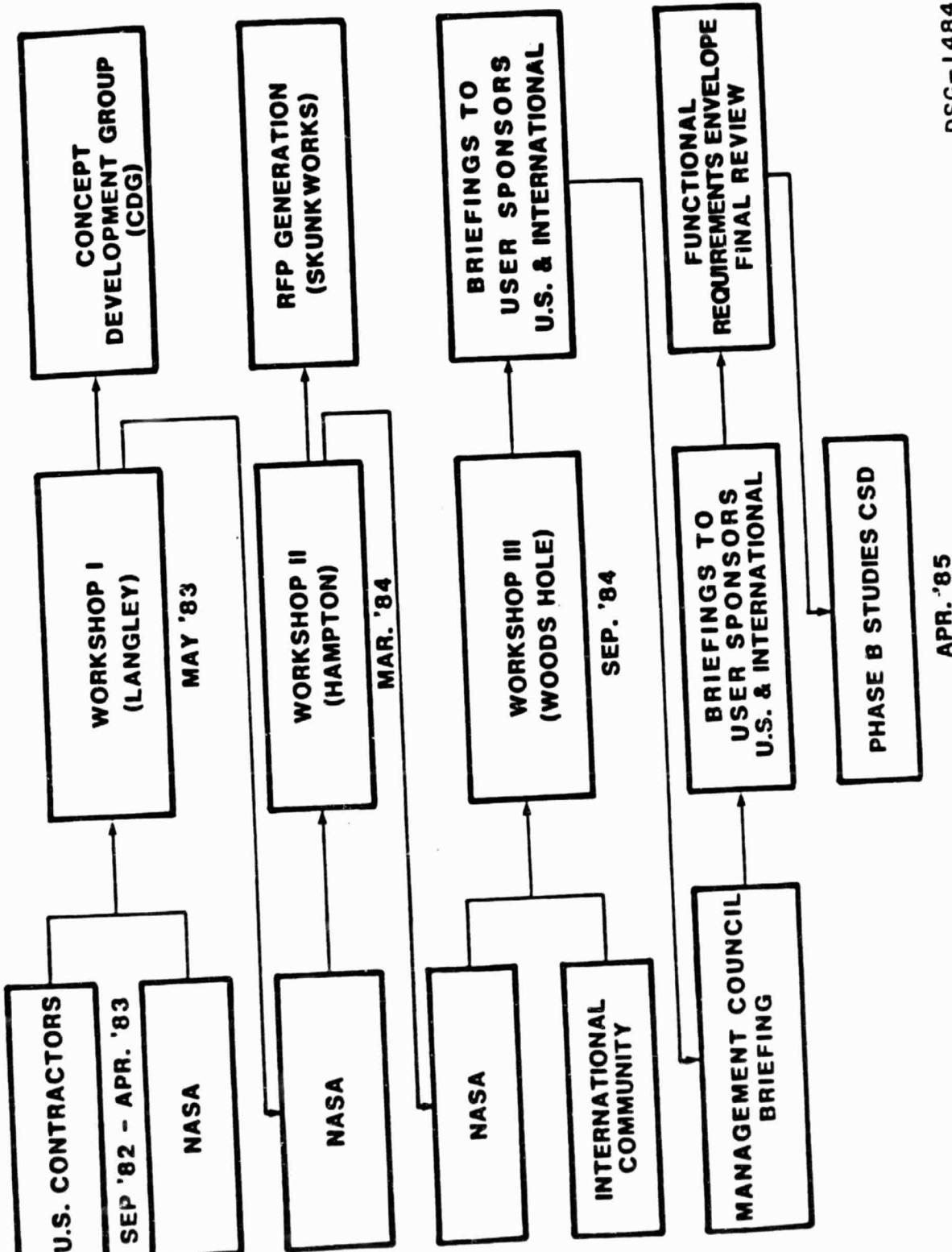
JAPANESE EXPERIMENT MODULE REFERENCE CONFIGURATION



FUNCTIONAL REQUIREMENTS ENVELOPE

- THE FUNCTIONAL REQUIREMENTS ENVELOPE PROVIDES A PERFORMANCE GOAL TO GUIDE THE INITIAL DEFINITION PERIOD OF NASA'S SPACE STATION PHASE B STUDIES
 - It supersedes Appendix C-2 of the RFP which stated user requirements
- THE FUNCTIONAL REQUIREMENTS ENVELOPE ADDRESSES USER REQUIREMENTS ONLY
 - It should encompass a wide variety of simultaneous user activity
 - It should not preclude any individual anticipated user activity
- THE FUNCTIONAL REQUIREMENTS ENVELOPE IS LARGER THAN THE USER ALLOCATIONS SPECIFIED IN THE RFP REFERENCE CAPABILITIES
 - Appendix C-4 of the RFP stated capabilities of the reference configuration
 - Appendix C-4 did not specify as many parameters as did C-2
- AFTER THE INTERFACE REQUIREMENTS REVIEW (IRR), THE FUNCTIONAL REQUIREMENTS ENVELOPE WILL BE SUPERSEDED BY THE PERFORMANCE ENVELOPE WHICH WILL SPECIFY THE SPACE STATION DESIGN REQUIREMENTS

SPACE STATION PROGRAM REVIEWS OF USER REQUIREMENTS



WHAT HAS HAPPENED SINCE THE RFP?

- INTERNATIONAL ENTRIES HAVE BEEN ADDED TO DATA BASE
 - Canadian plans modest
 - ESA subsequently reviewed and reduced first ten years
 - Japanese plans tied to elements provided by Japan
- NOAA ENTRIES FOR POLAR PLATFORM ADDED TO DATA BASE
- U.S. COMMERCIAL ENTRIES HAVE INCREASED
- OAST ENTRIES HAVE INCREASED
- OSSA HAS REVIEWED AND REDUCED ENTRIES FOR 1992-1994
- U.S. TOTAL RESOURCE REQUESTS HAVE BEEN FAIRLY STABLE
- DOD IS EXPRESSING INTEREST BUT HAS NO FIRM PLANS YET

SUM OF USER REQUIREMENTS

MAJOR PARAMETERS

	LOC			LOC + 10 YEARS		
	<u>C-4</u>	<u>C-2</u>	<u>Today</u>	<u>C-4</u>	<u>C-2</u>	<u>Today</u>
CO-ORBITING PLATFORMS						
Number	1	1	1	1	1	1
			SMALL DEMAND			SMALL DEMAND
POLAR PLATFORMS						
Number	1	1	3	1	1	12
MANNED ELEMENTS						
Average electrical power (kw)	50	75	123	250	221	375
User crew	6*	6	14	18*	12	27
Pressurized volume (M ³)	45-90	123	169	180	300	405
Payload launches/per year (dedicated STS)	-	5	14	-	5	12

* Total crew

WHAT CAN WE DO TODAY?

MOST FRUITFUL APPROACH TODAY IS TIME PHASING WHICH MUST TAKE INTO ACCOUNT:

- PEAK LOADING ON USERS TO DEVELOP LARGE PAYLOAD
ANTICIPATED AT IOC
 - Fiscal realism
 - Peak demand on DDT&E critical skills
 - Ability of community to keep pace with data flow
- DEMAND ON TRANSPORTATION CAPABILITY
 - STS
 - ELV
 - OMV
 - Potential need to limit "arrivals"
- DEMAND ON TDRSS
- PROBABLE SPACE STATION NEED TO PHASE UP OPERATIONS
DURING FIRST YEAR

MANNED ELEMENT

- THERE IS A WIDE VARIETY OF SPONSORS SUPPORTING A WIDER VARIETY OF ACTIVITY
- DEMANDS ON THE MANNED ELEMENT CHANGE FROM USER TO USER
 - Continuing presence *versus* short stay
 - High electrical power/low data rate and *vice versa*
 - Heavy crew demands *versus* minimal crew involvement
- WE DO NOT WANT TO SELECT A PAYLOAD LIST AT THIS TIME
- WE DO NOT WANT TO PRECLUDE ANY INDIVIDUAL USER ACTIVITY
- WE DO NOT WANT TO ALLOCATE STATION RESOURCES AT THIS TIME
- THE SUM OF THE USER REQUIREMENTS AS STATED IS TOO LARGE TO SERVE AS A DESIGN GOAL IN A REALISTIC SPACE STATION BUDGET ENVIRONMENT

MANNED ELEMENT ALGORITHMS

- CANADA, ESA, JAPAN
 - 80% of request in first 3 years and 100% thereafter
- U.S. COMMERCIAL MATERIALS RESEARCH, DEVELOPMENT, AND PRODUCTION
 - 80% of request in first 3 years and 100% thereafter
- U.S. GENERAL COMMERCIAL
 - Covered by "block allocation" in late 1990's
- OSSA GENERAL SCIENCE
 - 80% of request in first 3 years and 50% thereafter
- OSSA LIFE SCIENCE
 - 80% of request in all years
- OAST TECHNOLOGY DEVELOPMENT AND DEMONSTRATION
 - 10% of request in first 4 years and 50% thereafter

MANNED ELEMENT ALGORITHMS

U.S. TECHNOLOGY DEVELOPMENT AND DEMONSTRATION

- BUDGET REALISM NOT YET ESTABLISHED
 - Heavily front-loaded
 - Typically "place-holders"
- A NUMBER OF LARGE ITEMS TO BE ASSEMBLED
- DWELL TIME ON STATION GENERALLY SHORT
- HAVE ASSUMED 10% OF TOTAL REQUIREMENT IN FIRST FOUR YEARS AND 50% THEREAFTER

MANNED ELEMENT

MAJOR PARAMETERS

	<u>C-4</u>	<u>C-2</u>	<u>LOC</u>	<u>LOC + 10 YEARS</u>	<u>C-2</u>	<u>Recommendation</u>	<u>C-2</u>	<u>Recommendation</u>
AVERAGE ELECTRICAL POWER (KW)	50	75	80	221	375			
DATA TO GROUND (MBPS)	-	29.1	20*	52.5	135*			
NUMBER OF ATTACHED PAYLOADS	9	9	14	9	13			
PRESSURIZED VOLUME	45-90	123	120	300	330			
USER CREW	6**	6	10	12	20			
STS LAUNCHES	-	5	4	5	9			

*Includes video

**Includes station operating crew

FUNCTIONAL REQUIREMENTS ENVELOPE
MANNED ELEMENT
USERS ONLY¹

	<u>1992</u>	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>1996</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>	<u>2000</u>	<u>2001</u>
STS LAUNCHES ²	4	6	9	12	12	13	14	14	11	9
AVERAGE ELECTRICAL POWER (kW)	80	85	155	245	290	290	340	375	375	375
AVERAGE DATA RATE TO GROUND (MBPS)	20	75	140	160	165	145	165	145	160	135
PRESSURIZED VOLUME (M3) ³	120	125	200	270	295	300	325	325	325	330
USER CREW ⁴	10	11	14	17	18	18	17	18	20	20
EVA HOURS ⁵	412	368	462	509	810	915	1504	780	820	794
NUMBER OF ATTACHED PAYLOADS	14	15	12	13	15	18	15	14	15	13
OMV EVENTS ⁶	6	12	24	24+	24+	24+	24+	24+	24+	24+

FUNCTIONAL REQUIREMENTS ENVELOPE

MANNED ELEMENT

USERS ONLY

1. ALL PARAMETERS ARE FOR RESOURCES AVAILABLE TO THE USER AND DO NOT INCLUDE "OVERHEAD".
2. IN ADDITION TO USE OF 6000kg PAYLOAD ALLOCATION ON EACH OF FOUR LOGISTICS MODULES A YEAR, ASSUMES LAUNCHES OF 15000kg CAPABILITY DEDICATED TO PAYLOADS. DOES NOT INCLUDE OVERHEAD SUCH AS LAUNCH OF ADDITIONAL MODULES, OMV FUEL, ETC.
3. MULTI-USER LABORATORY VOLUME REQUIRED FOR USERS' INSTRUMENTATION. DOES NOT INCLUDE HABITATION VOLUME OR PRIVATELY SUPPLIED VOLUME DEDICATED TO A SINGLE USER
4. ASSUMES NINE HOUR WORK DAY AND SIX DAY WEEK. ASSUMES USER CREW WILL PERFORM PAYLOAD ASSOCIATED EVA AND RMS AND OMV PROXIMITY OPERATIONS.
5. PRODUCTIVE EVA WORK HOURS. NOT ADDITIVE. CREW REQUIRED TO PERFORM EVA INCLUDED IN "USER CREW" TOTALS.
6. NUMBER OF ASSEMBLY, SERVICING AND STAGING EVENTS TO BE SUPPORTED BY OMV. MAY REQUIRE TWO OMV ROUND TRIPS FOR SOME EVENTS. CAPABILITY SHOULD BE INCREASED AS RAPIDLY AS POSSIBLE.

ANTICIPATED USER ACTIVITY TECHNOLOGY DEVELOPMENT AND DEMONSTRATION

- INCLUDES AREAS OF:**

- Environmental effects**
- Large structures assembly and dynamics**
- Materials performance**
- Electrical power generation and storage techniques**
- Communications and data handling**
- Fluid management, transfer, and cryogenic storage**
- Attitude and figure control**
- Teleoperations and automation**
- Habitation, medical operations, and human factors**
- Tethers**
- Servicing**
- OMV and OTV capability enhancements**
- Solar concentrators**

PARTICIPATION IN TECHNOLOGY DEVELOPMENT & DEMONSTRATION

- NASA
- INDUSTRY
- UNIVERSITY
- DOD

OAST PROGRAM DEVELOPMENT STRATEGY
FOR
SPACE STATION-BASED RESEARCH AND TECHNOLOGY

MAY 21, 1985

65

PRESENTED BY:

JOHN L. ANDERSON
SPACE DIRECTORATE,
OAST
PROGRAM MANAGER
TECHNOLOGY UTILIZATION
OF SPACE STATION

PRESENTED TO:

IN-SPACE R&T WORKSHOP
of the
AERONAUTICS & SPACE
ENGINEERING BOARD
at
NASA Langley Research Center

SPACE STATION-BASED RESEARCH AND TECHNOLOGY OAST PROGRAM DEVELOPMENT STRATEGY

PRESENTATION OUTLINE

- PURPOSE/OBJECTIVE/RATIONALE
- BACKGROUND - STS FLIGHT EXPERIMENTS
- PROGRAM DEVELOPMENT
 - APPROACH
 - ACTIVITIES
 - PLAN
- ISSUES

PURPOSE

THE PURPOSE OF THIS PROGRAM WILL BE TO:

- POSTURE OAST TO FULLY UTILIZE SPACE STATION FOR TECHNOLOGY PURPOSES
- ESTABLISH COMPREHENSIVE EFFORT TO EXPAND THE IN-SPACE R&T BASE
- EXPAND OAST CAPABILITY TO ENGAGE IN OUTSIDE JOINT VENTURES AND COLLABORATIONS

OBJECTIVE

TO ESTABLISH A PROGRAM LEADING TO BROAD UTILIZATION OF THE SPACE STATION AS A VERSATILE LONG-TERM FACILITY FOR IN-SPACE RESEARCH AND TECHNOLOGY EXPERIMENTS

THE OBJECTIVES OF THIS PROGRAM WILL BE:

- UTILIZE SPACE STATION AS A PLATFORM FOR NASA R&T SUPPORTING DISCIPLINE TECHNOLOGIES
- UTILIZE SPACE STATION AS A TEST BED FOR IDENTIFYING SYSTEMS PERFORMANCE TO VERIFY AND VALIDATE PREDICTIVE METHODS DURING CONSTRUCTION, ASSEMBLY AND OPERATION
- UTILIZE STS, EXPERIMENT CARRIERS, COMMERCIAL AND INTERNATIONAL IN-SPACE FACILITIES FOR APPROPRIATE PRECURSOR ACTIVITIES
- DETERMINE AND EXERCISE APPROPRIATE OAST LEADERSHIP IN THE TECHNOLOGICAL USE OF SPACE STATION FOR THE BROAD USER COMMUNITY

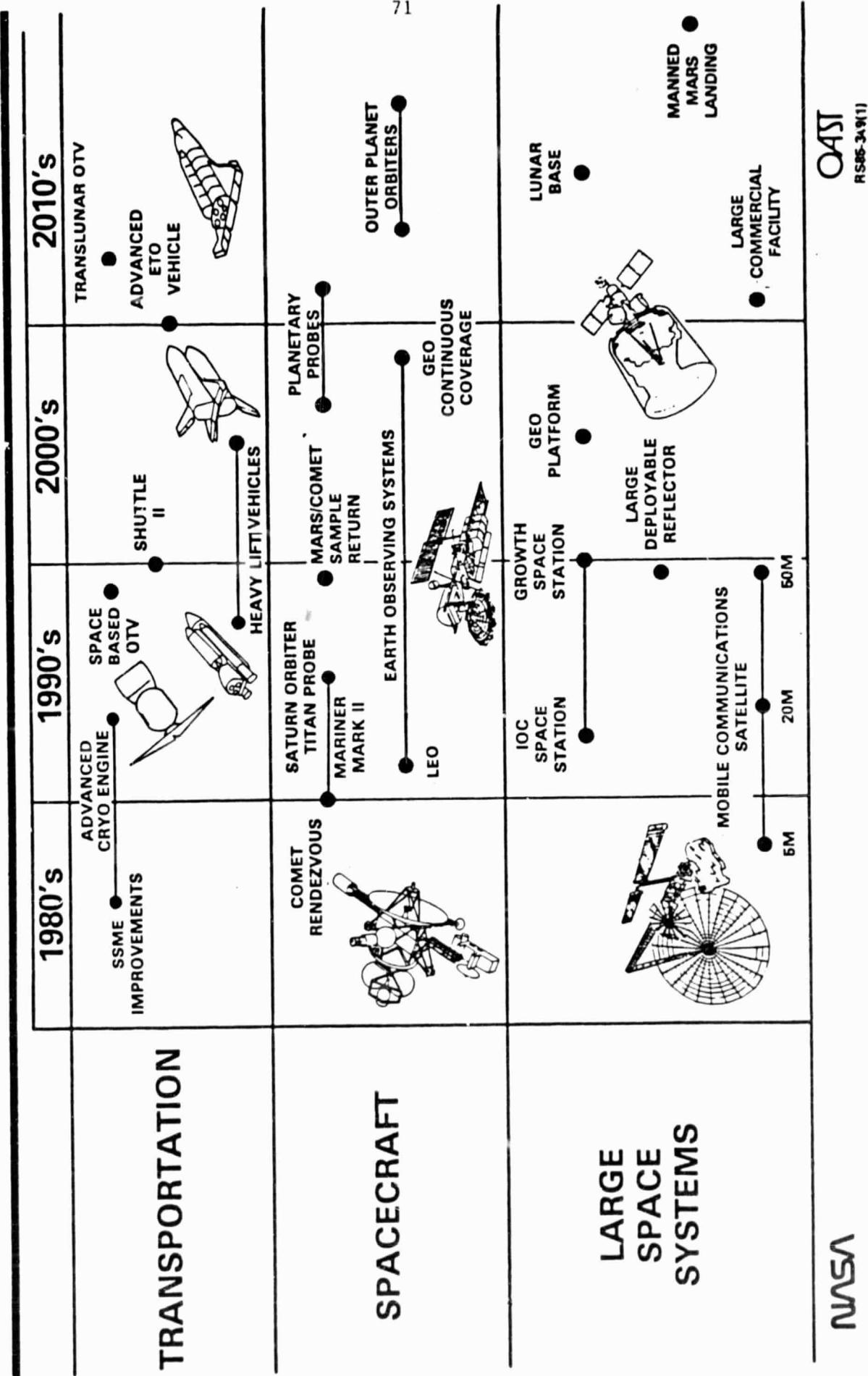
WHY SPACE STATION-BASED R&T

- SHUTTLE HAS BEEN USED TO COMPLEMENT OAST GROUND-BASED R&T
- SHUTTLE HAS DEMONSTRATED FEASIBILITY AND UTILITY OF SPACE FOR TECHNOLOGY RESEARCH AND PROOF-OF-CONCEPT EXPERIMENTS
- SHUTTLE USE IS CONSTRAINED BY AVAILABLE ON-BOARD SERVICES, ON-ORBIT STAY TIME AND PRIORITY PAYLOAD MANIFESTING
- SPACE STATION WILL PROVIDE PERMANENT FACILITY WITH SIGNIFICANTLY INCREASED CAPABILITY FOR IN-SPACE R&T

UNIQUE SPACE STATION CONDITIONS

- LONG DURATION TEST TIMES
- MORE CONFIGURATION OPTIONS (SIZE; ORBITAL INTEGRATION; FREE FLYERS)
- GREATER RESOURCES (POWER; CREW ATTENTION; INTERPLATFORM SUPPORT)
- ORBITAL CONSTRUCTION OR ASSEMBLY
- LARGE SCALE SYSTEMS ACCOMMODATION
- CO-ORBITING PLATFORMS (VIBRATION ISOLATION; CONTAMINATION REDUCTION)

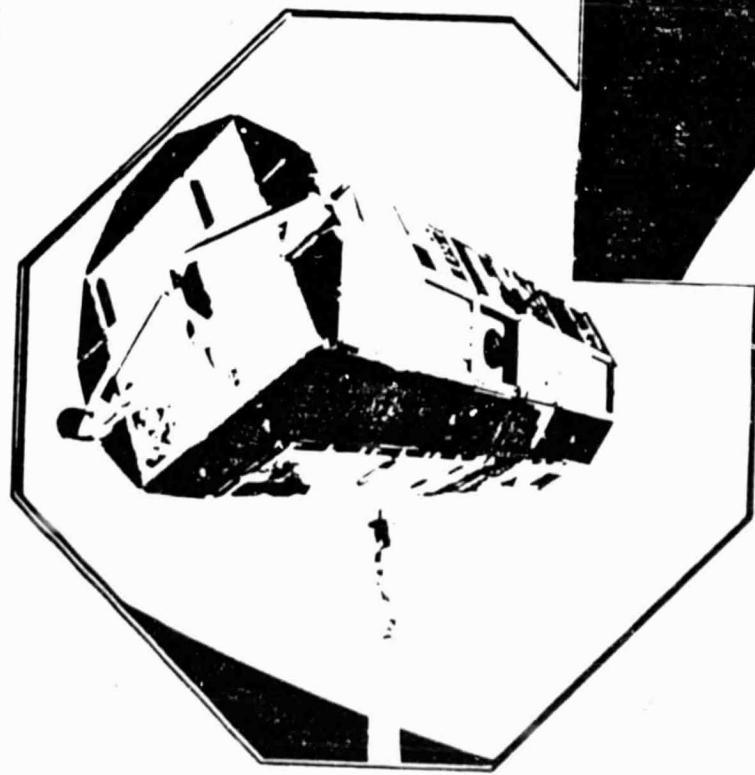
NATIONAL MISSIONS FOR TECHNOLOGY FOCUS



IN-SPACE EXPERIMENTS

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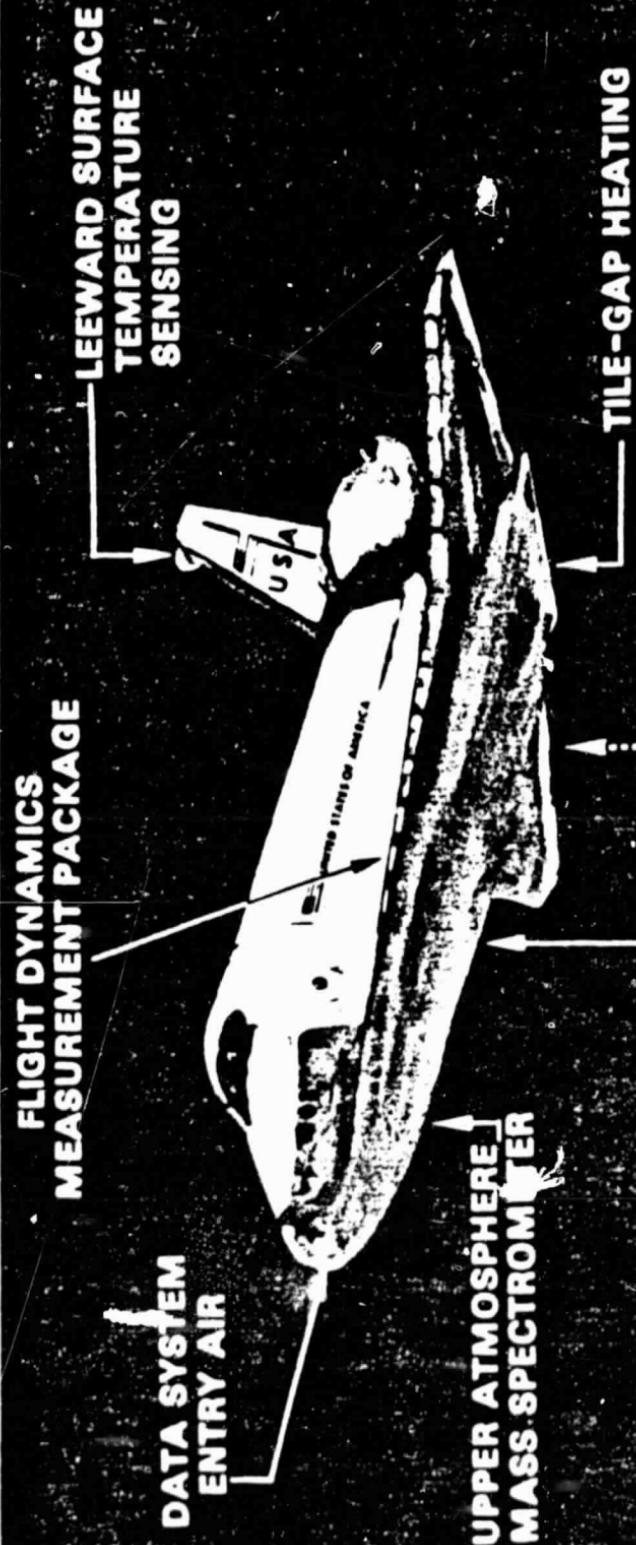
- OEX
- SAE
- LDEF
- VOLT
- TEMP
- CRYO-FLUID
MANAGEMENT
- CONTROL OF
FLEXIBLE
STRUCTURES
- AEROASSISTED
OTV
- ENTRY RESEARCH
VEHICLE

NASA

OAST NASA HQ 1084-1483(1)
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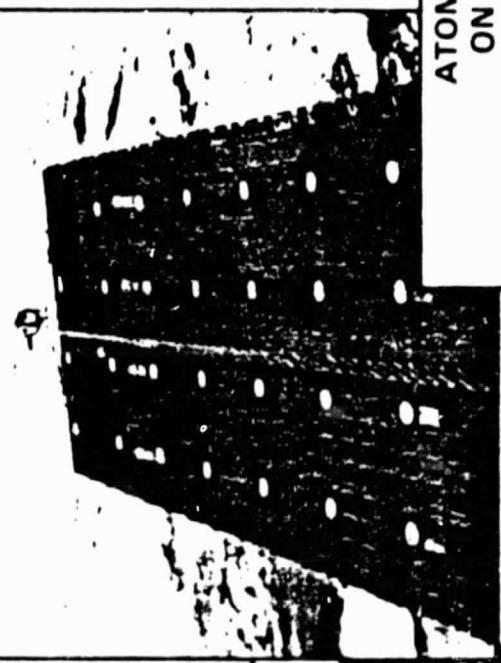
OAST

ORBITER EXPERIMENTS

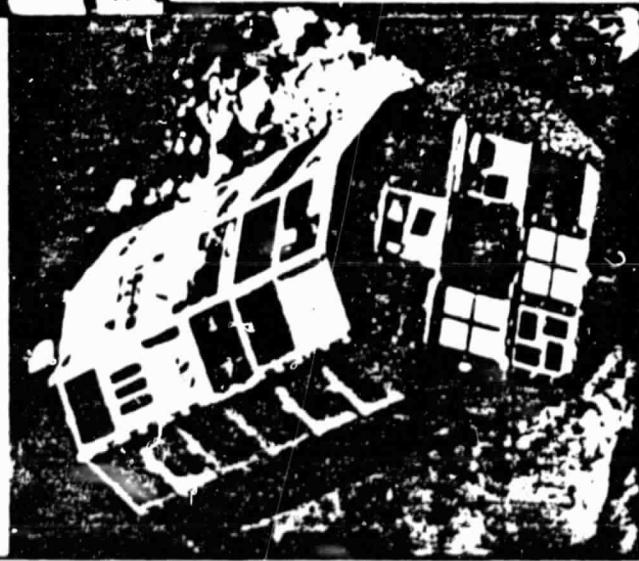


IN-SPACE RESEARCH

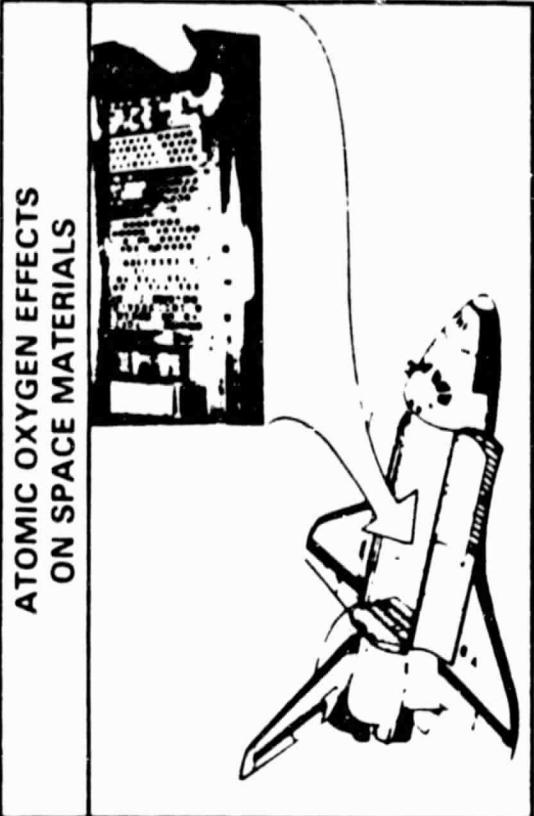
SOLAR ARRAY FLIGHT EXPERIMENT



LONG DURATION
EXPOSURE FACILITY



ATOMIC OXYGEN EFFECTS
ON SPACE MATERIALS



NASA

OAST
85-59413

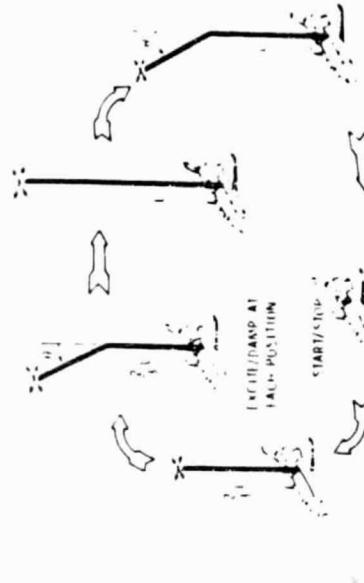
STRUCTURES

CONTROL OF FLEXIBLE STRUCTURES



- STRUCTURE/CONTROLS INTERACTIONS OF LARGE FLEXIBLE STRUCTURES
 - VERIFY ANALYTICAL MODELS
 - DEVELOP GROUND-TEST METHODOLOGY
 - VALIDATE
 - TECHNIQUES FOR STRUCTURAL CHARACTERIZATION
 - DISTRIBUTED CONTROL TECHNIQUES
 - SPACE DEPLOYMENT OF LARGE SYSTEMS

BEAM DYNAMICS MODEL



FLIGHT PROGRAM

- TWO FLIGHT ARTICLES
 - BEAM DYNAMICS
 - 3-D DYNAMICS
- FOUR FLIGHTS OF INCREASING COMPLEXITY
- PLANNED FLIGHTS - 1988, 1989, 1990

- FLIGHT TEST FOR STRUCTURAL DYNAMICS CHARACTERIZATION

MEI

PROGRAM DEVELOPMENT

NEAR-TERM APPROACH

1. SUPPORT DESIGN REQUIREMENTS DEFINITION FOR SPACE STATION
2. IDENTIFY AND ADVOCATE PRECURSOR IN-SPACE R&T EXPERIMENTS
3. CHARACTERIZE SPACE STATION-BASED R&T PROGRAMMATIC OPTIONS
4. EXERCISE APPROPRIATE OA&T MANAGEMENT ROLE IN PLANNING FOR TECHNOLOGY USE OF SPACE STATION

SPACE STATION DESIGN REQUIREMENTS SUPPORT

- **R&T EXPERIMENT CONCEPTS**
 - TECHNOLOGY DEVELOPMENT MISSIONS (TDM's)
 - ORIGINATION AND SCOPE
 - LaRC WORKSHOP REVIEW
- **ANALYSIS OF TDM DATA BASE**
 - ENVELOPE OF R&T EXPERIMENT REQUIREMENTS; TO BE MET BY SPACE STATION
 - CENTER EVALUATION & PRIORITIZATION
 - TIME PHASING
 - CLUSTER REQUIREMENTS
- **SUPPLEMENTAL TDM's**
 - CENTER IDENTIFICATION OF VOIDS
 - CENTER DESCRIPTION OF APPROPRIATE EXPERIMENTS

PROPOSED RESEARCH CLUSTERS

- LARGE FLEXIBLE STRUCTURES
- AUTOMATION AND ROBOTICS
- IN-SPACE CONTAMINATION/ENVIRONMENTAL EFFECTS
- FLUID BEHAVIOR AND MANAGEMENT

OAST USE OF TDM's

- INITIAL CATALOG OF IN-SPACE R&T EXPERIMENT CONCEPTS
- BASIS FOR DERIVING EARLY ENVELOPE OF EXPERIMENT REQUIREMENTS
- PRELIMINARY BASIS FOR DETERMINING IN-SPACE R&T CAPABILITY NEEDED (SERVICES AND FACILITIES)
- GUIDE FOR CATEGORIZING POTENTIAL EXPERIMENTS INTO PROGRAMMATIC CLUSTERS OR THEMES

SPACE STATION-BASED R&T

CHARACTERIZING PROGRAMMATIC OPTIONS

- TECHNOLOGY REQUIREMENTS DETERMINATION
- TECHNICAL CONTENT OF PROGRAM
- EXPERIMENT PROGRAM STRUCTURE

CANDIDATE TECHNOLOGY THEMES FOR SPACE STATION-BASED R&T

- LARGE FLEXIBLE STRUCTURES
- AUTOMATION AND ROBOTICS
- IN-SPACE CONTAMINATION/ENVIRONMENTAL EFFECTS
- FLUID BEHAVIOR AND MANAGEMENT
- OTHERS?

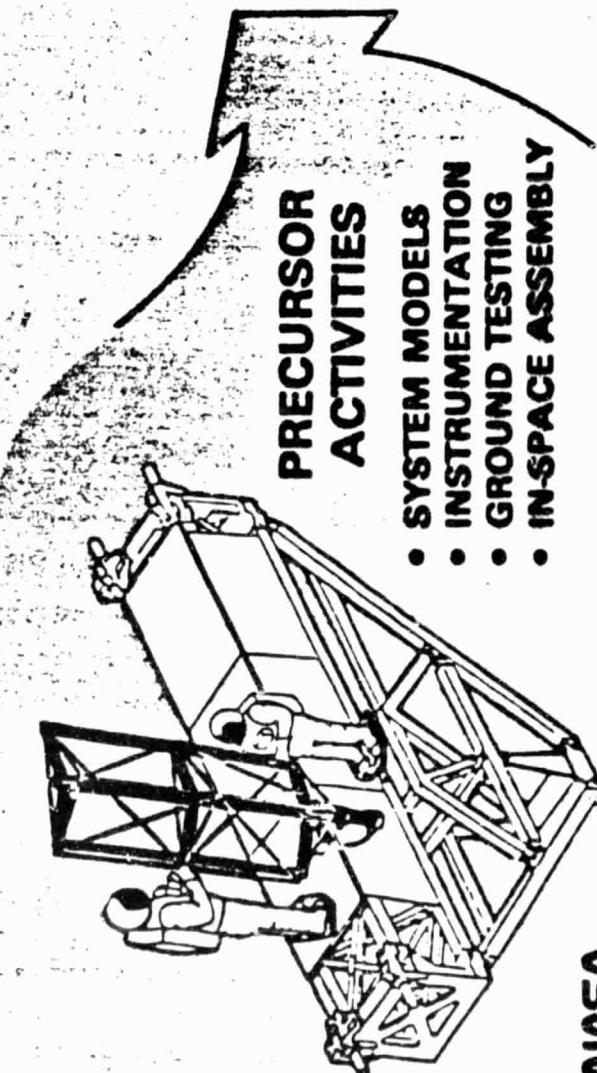
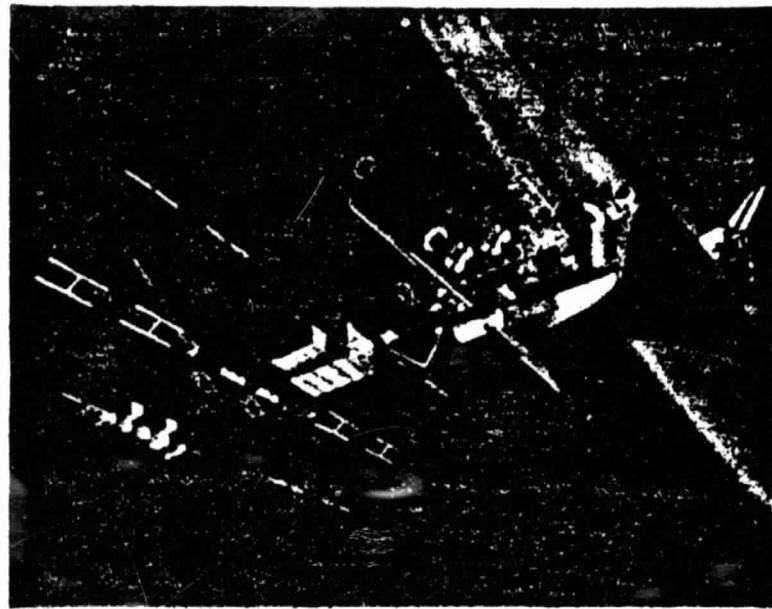
ASSEMBLY/INSTRUMENTED SPACE STATION

SHUTTLE/OEX

INSTRUMENTED SPACE STATION



RESEARCH OPPORTUNITY



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STRUCTURES/CONTROLS
RESEARCH OPPORTUNITY

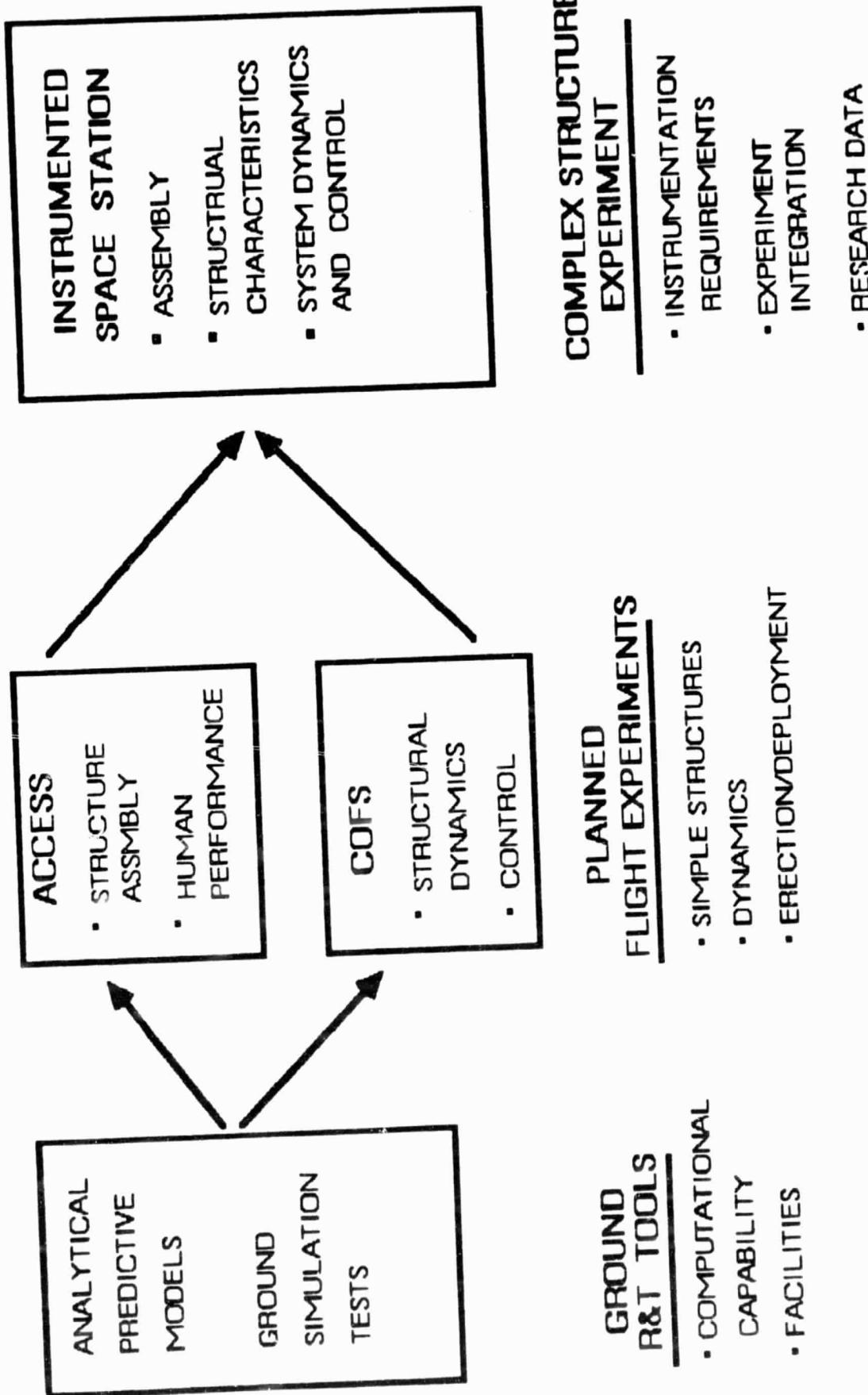
- SYSTEM MODELS
- INSTRUMENTATION
- GROUND TESTING
- IN-SPACE ASSEMBLY

OAST
RESEARCH OPPORTUNITY

NASA

DYNAMICS AND CONTROLS EXPERIMENTS

83



IN-SPACE CONTAMINATION/ENVIRONMENTAL EFFECTS EXPERIMENTS

PROBLEMS

- RCS PLUME
- CONTAMINANTS
- GLOW PROCESSES
- SURFACE INTERACTIONS
- CONDENSATION COEFFICIENTS

ATOMIC OXYGEN

- CORROSION PROCESSES
- SUBSURFACE CONTAMINANT RELEASES
- RELEASE RATES
- MATERIALS VALIDATION

PLASMA RAM/WAKE

- FLOW FIELD
- CHARGE/DISCHARGE
- INDUCED FIELDS
- SENSOR PERFORMANCE

- TO CHARACTERIZE PRIMARY EFFECTS AND INTERACTIONS
- TO COMPLEMENT GROUND-BASED, TESTING OF SOLUTION OPTIONS
- TO VALIDATE TECHNOLOGY FOR ACCOMMODATING EFFECTS

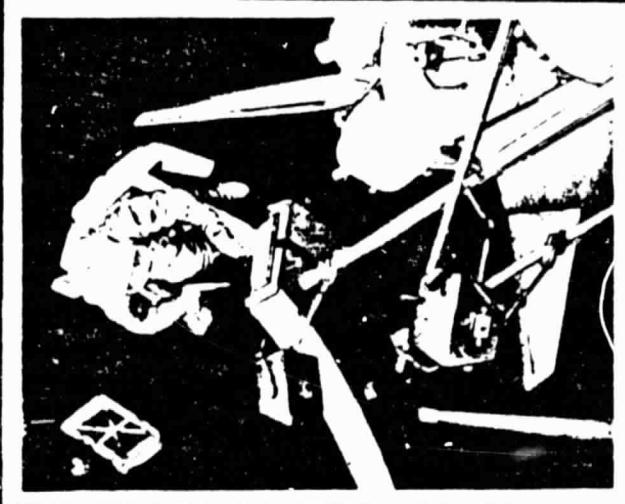
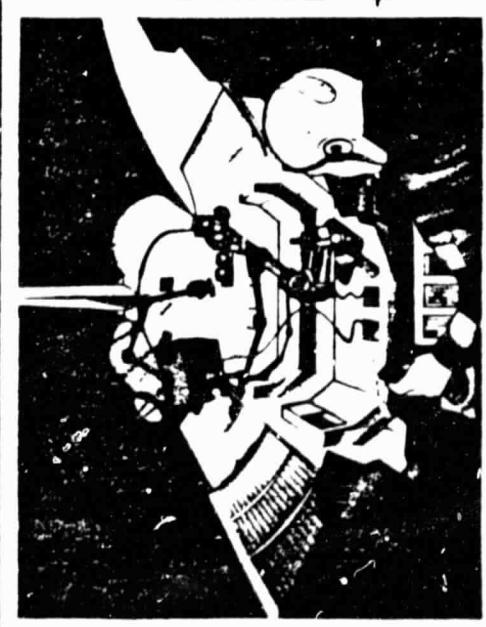
SHUTTLE
BASED EXPERIMENTS

SPACE STATION
BASED EXPERIMENTS

PROPOSED 'SMART' PROGRAM

(SPACE MISSIONS FOR AUTOMATION AND ROBOTICS TECHNOLOGIES)

- MULTI-FLIGHT SHUTTLE-BASED AUTOMATION AND ROBOTICS TEST FACILITY
- EVALUATE TECHNOLOGIES AND REAL TIME OPERATIONAL CONCEPTS
- PROGRESSIVE COMPLEXITY
 1. IN BAY, TWO-ARM TELEOPERATOR COOPERATION
 2. RMS-ATTACHED ROBOTS
 3. SUPERVISORY, LEASHED ROBOTS
 4. FREE-FLYING MULTIPLE ROBOTS WITH COMMON WORK OBJECTIVE
- FACILITY OPEN TO ALL POTENTIAL INVESTIGATORS



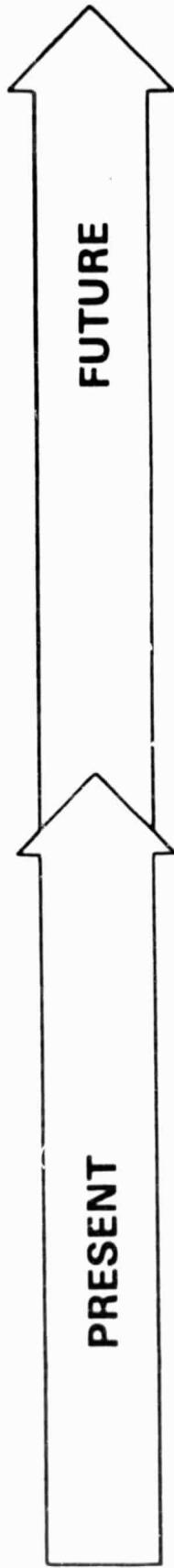
AUTONOMOUS SPACE SYSTEMS

Q4ST
RS 86 644031

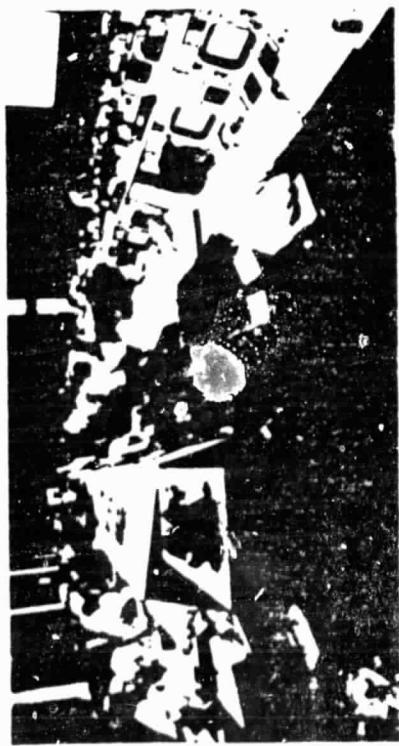
NASA



INCREASING
SPACE
OPERATIONS



DECREASING
GROUND
OPERATIONS



EXPERIMENT PROGRAM STRUCTURE

- FEW CATEGORIES (4-5)
- TYPES OF CATEGORIZATION
 - MULTI-DISCIPLINARY INDEPENDENT EXPERIMENT CLUSTERS
 - FUNCTIONAL OR OPERATIONAL THEMES
- CATEGORIES SHOULD PERMIT DETERMINATION OF A RANGE OF R&T CAPABILITIES (support services, tools, facilities) BASED ON THE GENERAL DEFINITION OF FUTURE EXPERIMENT REQUIREMENTS (wind tunnel analogy)

PROGRAMMATIC THEMES AS CATEGORIES FOR R&T EXPERIMENTS

- A THEME MAY BE FUNCTIONAL OR OPERATIONAL AS WELL AS MULTI-DISCIPLINARY
- IT MAY BE COMPRISED OF A PROGRESSIVE SERIES OF INTERRELATED EXPERIMENTS
- IT MAY BE PROGRESSIVE IN STEPS TOWARD A BROAD FUNCTIONAL OR OPERATIONAL CAPABILITY WITH A STATED PROGRAMMATIC GOAL, MEASURE OF MATURITY OR RANGE LIMITS

CANDIDATE THEMES: EXAMPLE EXPERIMENT PROGRESSIONS

<p>LARGE FLEXIBLE STRUCTURES</p>	<p>EXTENSION DEPLOYMENT CONTROL - RIGID INSTRUMENTED STATION</p>	<p>MOD. ASSEMBLY CONTROL/FLEXIBLE STATION</p>	<p>CONSTRUCTION ADAPTIVE CONTROL TETHERS</p>
<p>AUTOMATION AND ROBOTICS</p>	<p>TELEOPERATORS DYNAMICS OPTICAL COMM & RANGE</p>	<p>ROBOTICS CONTROL COOPERATION</p>	<p>MINIMAZ SUPERVISION TRAFFIC CONTROL</p>
<p>CONTAMINATION/ ENVIRONMENTAL EFFECTS</p>	<p>ATOMIC OXYGEN PLUME CONTAMINATION OUTGASSING</p>	<p>PLASMA RAM/WAKE GLOW</p>	<p>SPACE DEBRIS RF INTERFERENCE</p>
<p>FLUID BEHAVIOR AND MANAGEMENT</p>	<p>CRYOGEN TRANSFER FLUID MECHANICS COMBUSTION</p>	<p>CLOSED LIFE SUPPORT</p>	<p>BOILING LIQUIDS</p>

OAST NEAR TERM PLAN AND MILESTONES

- MAY - CENTER PROPOSED EXPLORATORY STUDIES TO DEFINE CANDIDATE THRUSTS FOR SPACE STATION R&T EMPHASIS
- MAY - ASEB WORKSHOP PRELIMINARY RECOMMENDATIONS
- JUNE - OAST INTEGRATION OF ABOVE INPUTS JULY
- AUG - OAST DRAFT PROGRAM DEVELOPMENT PLAN

ISSUES

- WHAT ARE THE UNIQUE SPACE OPERATIONAL REQUIREMENTS THAT REQUIRE IN-SPACE R&T ?
- WHAT TECHNOLOGICAL AREAS ARE MOST CRITICAL FOR OR PROVIDE THE GREATEST LEVERAGE FROM IN-SPACE EXPERIMENTATION?
- WHAT CRITERIA SHOULD BE USED FOR EVALUATING AND PRIORITIZING IN-SPACE R&T EXPERIMENT PROPOSALS?
- WHAT ARE THE "WIND TUNNEL-EQUIVALENT" R&T CAPABILITIES FOR SPACE STATION-BASED R&T?

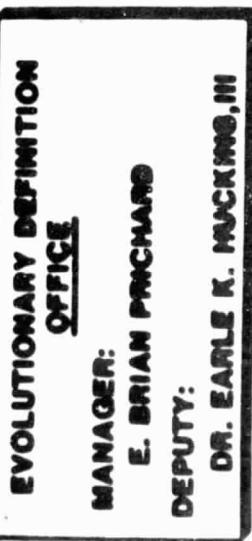
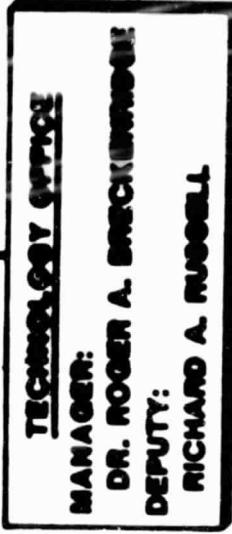
LANGLEY SPACE STATION ORGANIZATION

W. Ray Hook, Manager
Space Station Office

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SPACE STATION OFFICE



TECHNOLOGY UTILIZATION TASKS

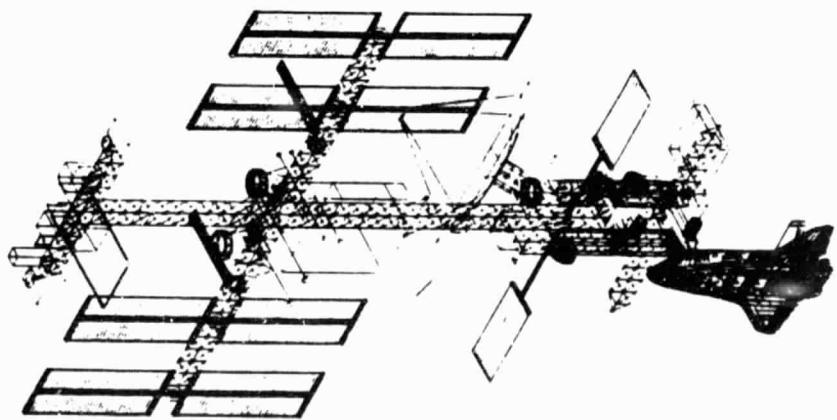
- GENERATE, COORDINATE AND MANAGE TECHNOLOGY BUDGET AND TASKS
- GENERATE REALISTIC DATA BASE
- REPRESENT ALL TECHNOLOGY USERS
- GENERATE AND MAINTAIN OUTREACH PROGRAM
- INSURE SPACE STATION ACCOMMODATES TECHNOLOGY USERS
- GENERATE AND MAINTAIN "CUSTOMER FRIENDLY" PROGRAM

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SPACE STATION
TECHNOLOGY
UTILIZATION

ASEB BRIEFING
MAY 21, 1985

RICHARD A. RUSSELL
LANGLEY RESEARCH CENTER



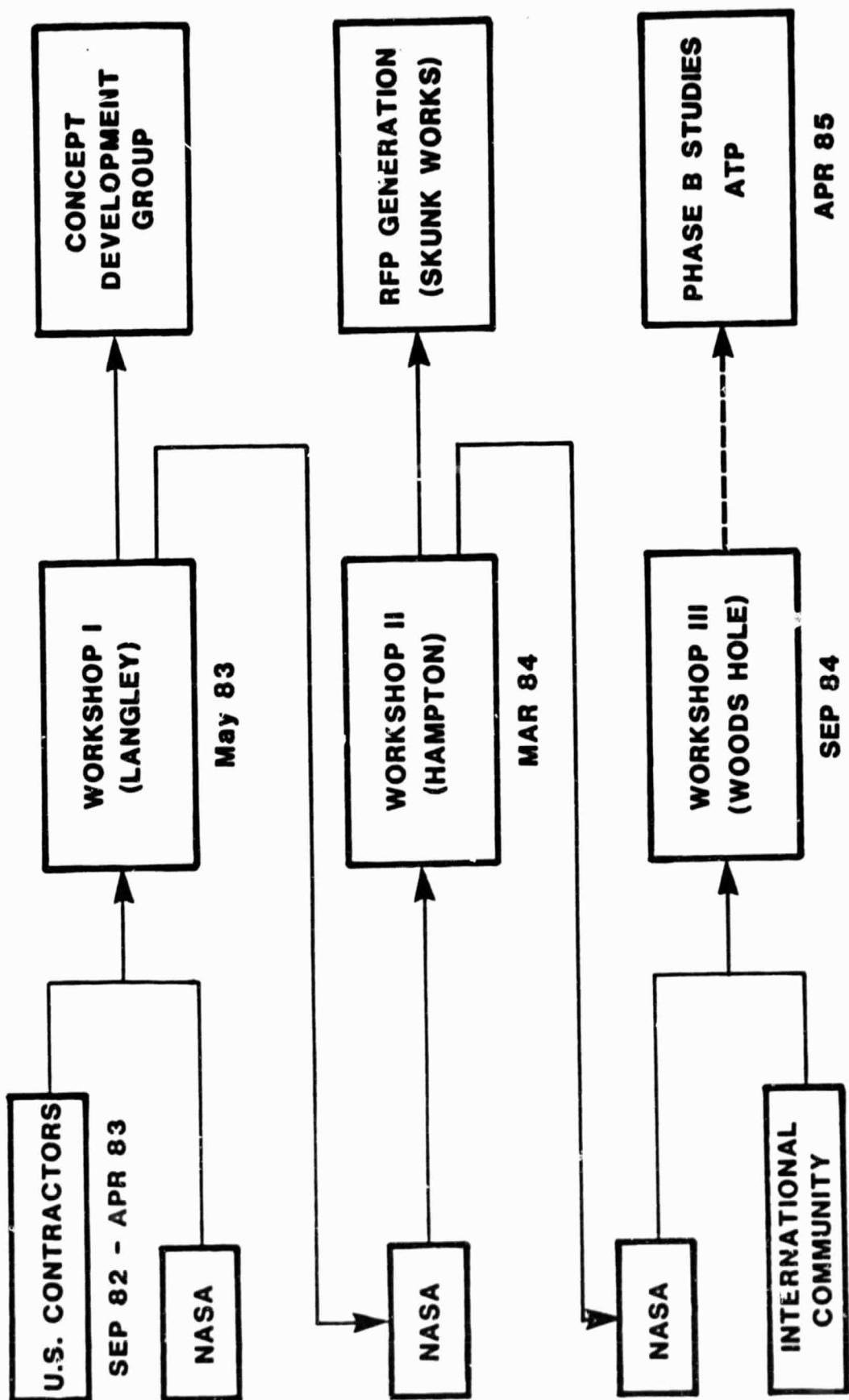
OUTLINE

- BACKGROUND
- FUNDING
- TECHNOLOGY UTILIZATION ACTIVITIES
- RECOMMENDATIONS

BACKGROUND

BACKGROUND

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DSC-1424

TECHNOLOGY UTILIZATION OF SPACE

BACKGROUND

JULY 1982 - MAY 1983

- NASA FIELD CENTER AND INDUSTRY SURVEY
- 78 EXPERIMENTS IDENTIFIED AND GROUPED INTO 31 TDM'S
- TDM PRIORITIZATION AND TIME PHASING
- PRELIMINARY DEFINITION OF FUNCTIONAL REQUIREMENTS
- COMPIRATION INTO PRELIMINARY DATA BASE

MAY 2-6, 1983 - MISSION SYNTHESIS WORKSHOP I - Langley Res. Ctr.

- MISSION REQUIREMENTS UPDATING

MARCH 5-8, 1984 - MISSION SYNTHESIS WORKSHOP II - HAMPTON, VA

- MISSION REQUIREMENTS UPDATING OF 21 OF 31 TDM'S

AUGUST 1984

- INDIVIDUAL EXPERIMENTS MADE TDM'S TO AID REQUIREMENTS VALIDATION ACTIVITY

SEPTEMBER 24 - OCTOBER 4, 1984 - MISSION SYNTHESIS WORKSHOP III
WOODS HOLE, MA

- MISSION REQUIREMENTS UPDATING OF 53 OF 69 TDM'S USING REVISED DATA BASE FORMAT
- INCLUSION OF INTERNATIONAL MISSIONS

DSG-1266

IOC PRIORITY EXPERIMENTS

- TDM 2011 SPACECRAFT MATERIALS PERFORMANCE
- TDM 2071 FLIGHT DYNAMICS IDENTIFICATION
- TDM 2132 ADVANCED RADIATOR CONCEPTS *
- TDM 2153 SOLAR DYNAMIC POWER TEST FACILITY *
- TDM 2311 LONG-TERM CRYOGENIC FLUID STORAGE
- TDM 2411 ADVANCED ADAPTIVE CONTROL
- TDM 2421 ACTIVE OPTICS TECHNOLOGY *
- TDM 2441 MICROELECTRONICS DATA SYSTEM
- TDM 2472 ADVANCED AUTOMATION TECHNOLOGY *
- TDM 2570 OTV SYSTEMS TECHNOLOGY *

* POTENTIAL MISSION DRIVERS

SPACE STATION SYSTEM PERFORMANCE TECHNOLOGY EXPERIMENT

Experiment Disciplines

- Structures
- Controls
- Structural Dynamics
- Deployment & Assembly
- Operations

SYSTEM PERFORMANCE TECHNOLOGY EXPERIMENT

OBJECTIVE:

To Employ the IOC Space Station System to Verify and Validate Analytical and Pre-Flight Predictions of System Operational Characteristics.

APPROACH:

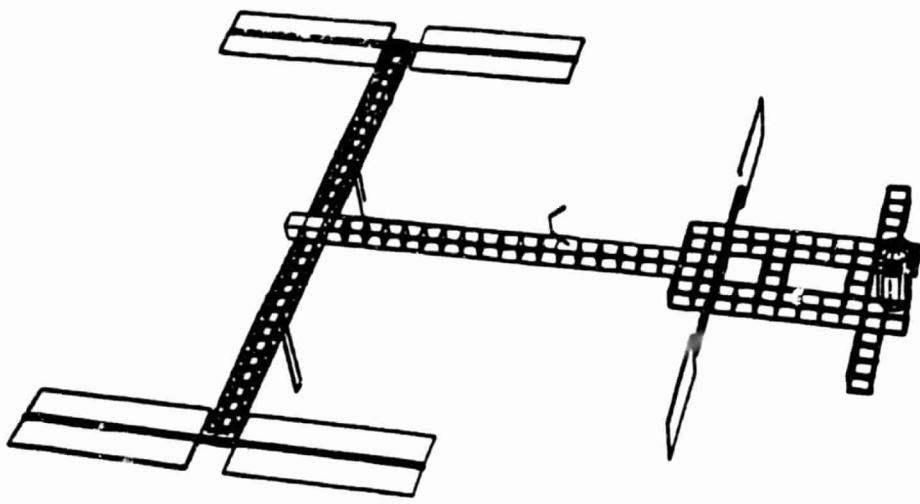
A Series of Experiments will be Defined to Collect Data to Compare the As-Built Performance of the Space Station with Predictions Obtained from Analysis and Pre-Launch Tests. All Configurations of the Station will be Modeled and Instrumented to Gather Engineering Data Necessary for the Validation.

SCOPE:

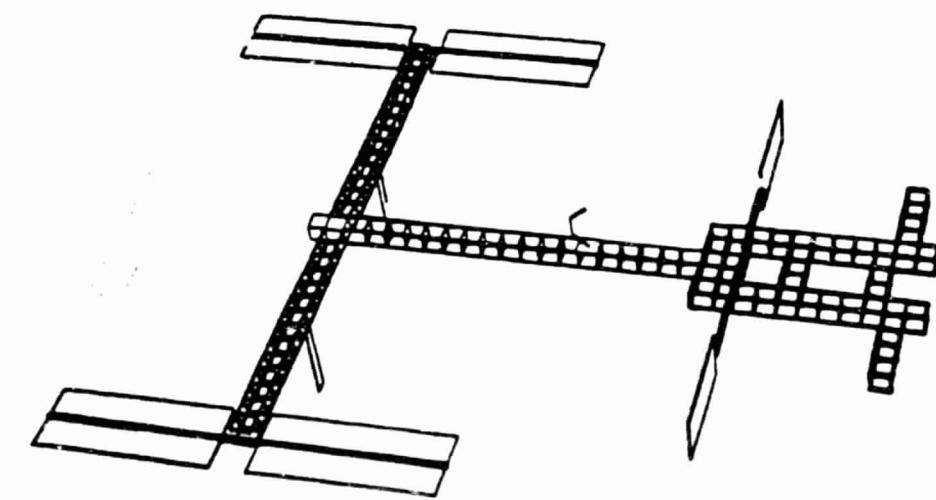
Experiments will Encompass All Phases of the Station Construction and will Continue Past IOC Utilizing the Operational Station as an Experimental Platform.

SPACE STATION BUILDUP TO LOC

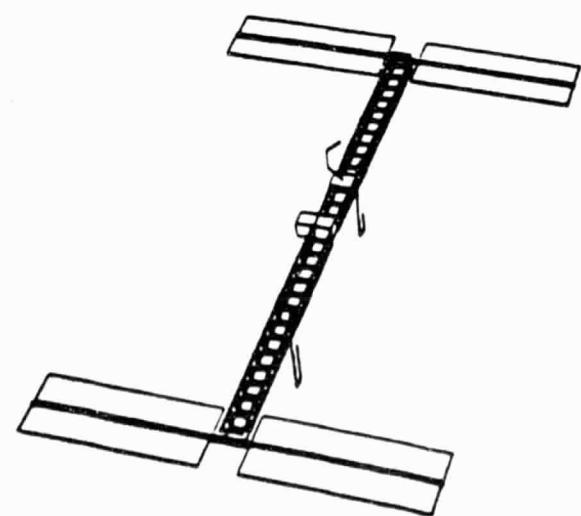
104



Flight 3



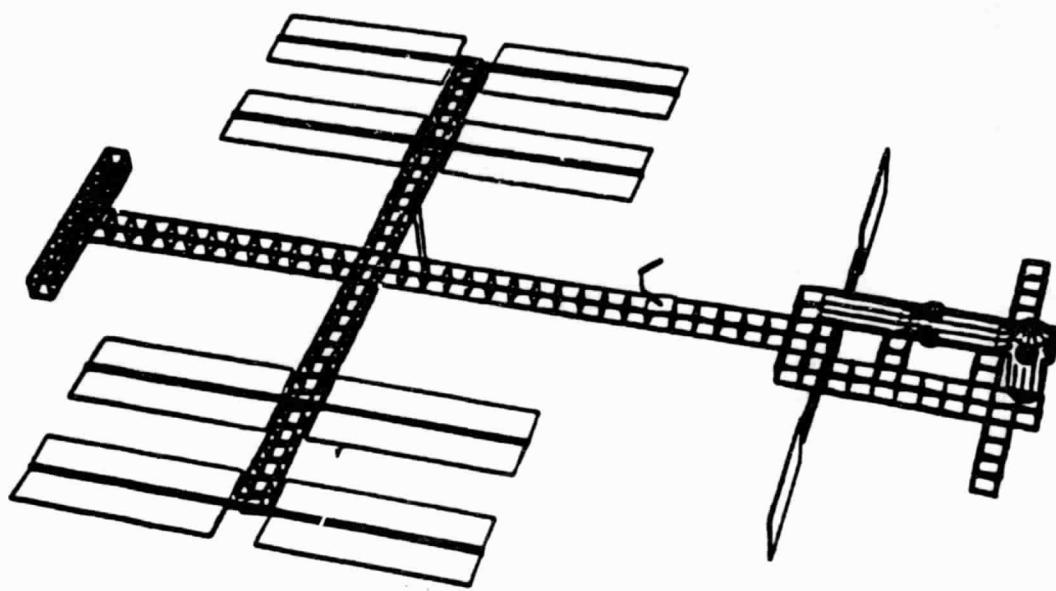
Flight 2



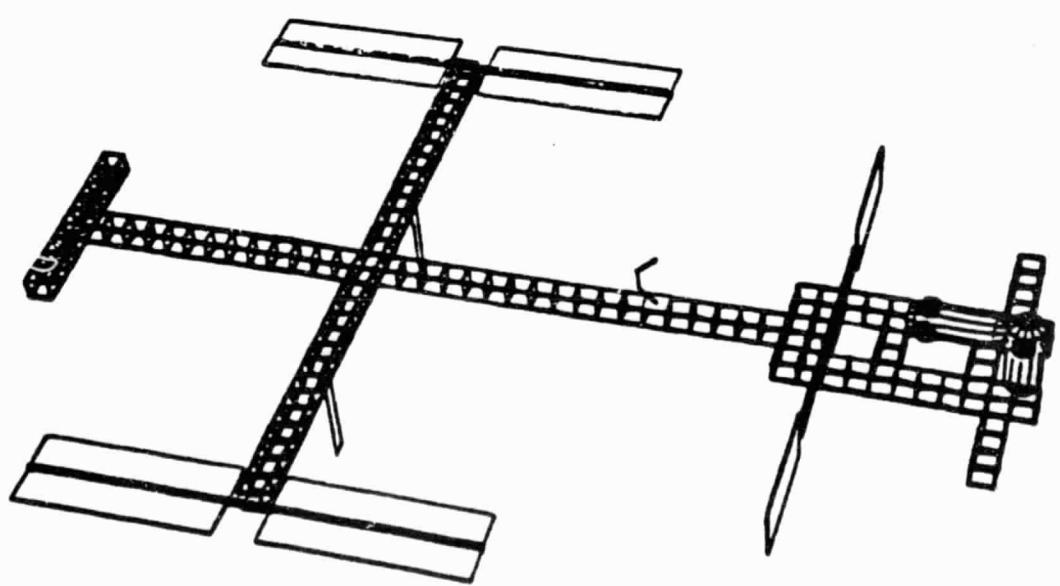
Shuttle Flight 1

SPACE STATION BUILDUP TO LOC

105



Flight 5

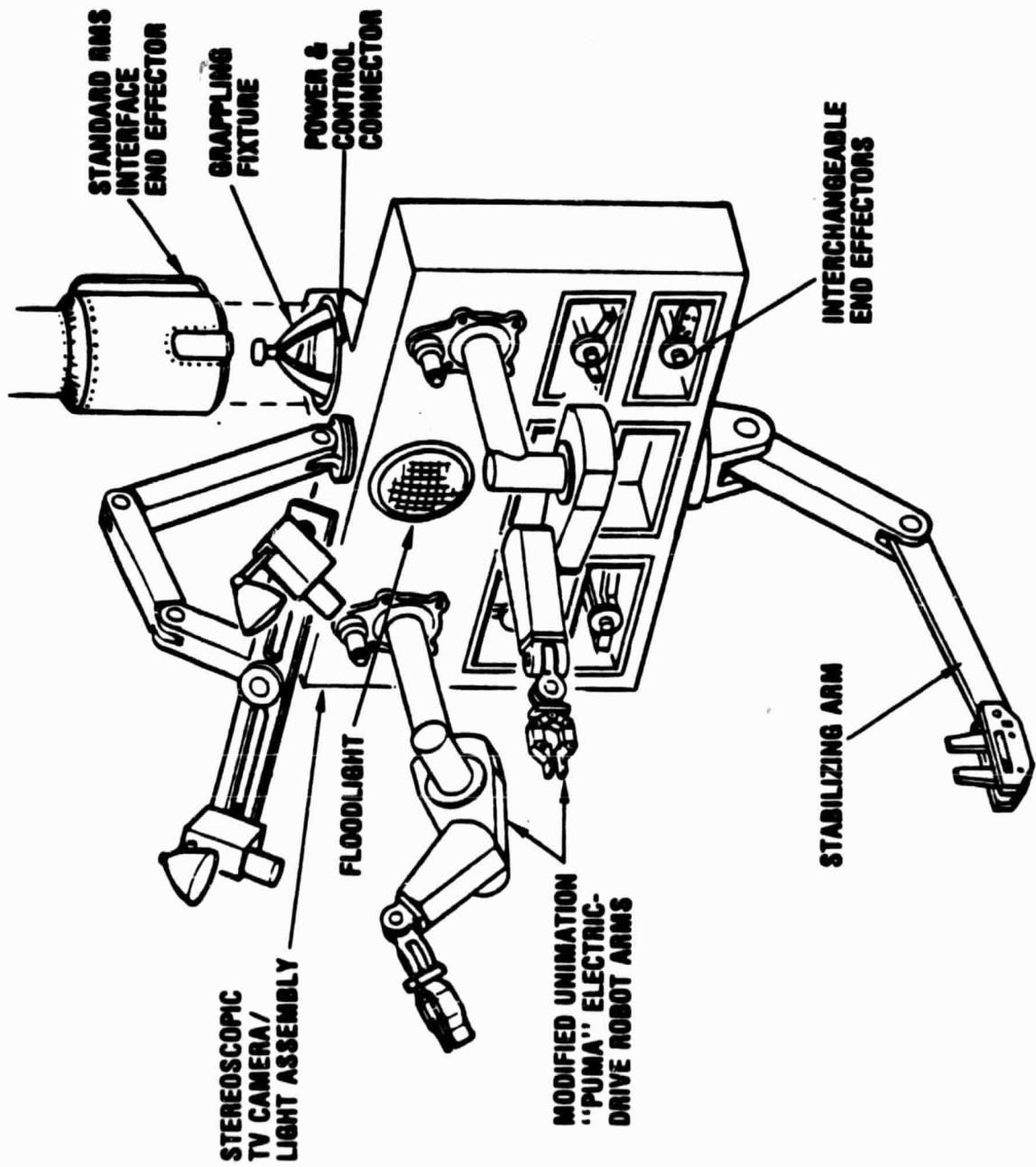


Shuttle Flight 4

AUTOMATION AND ROBOTICS

RMS END EFFECTOR

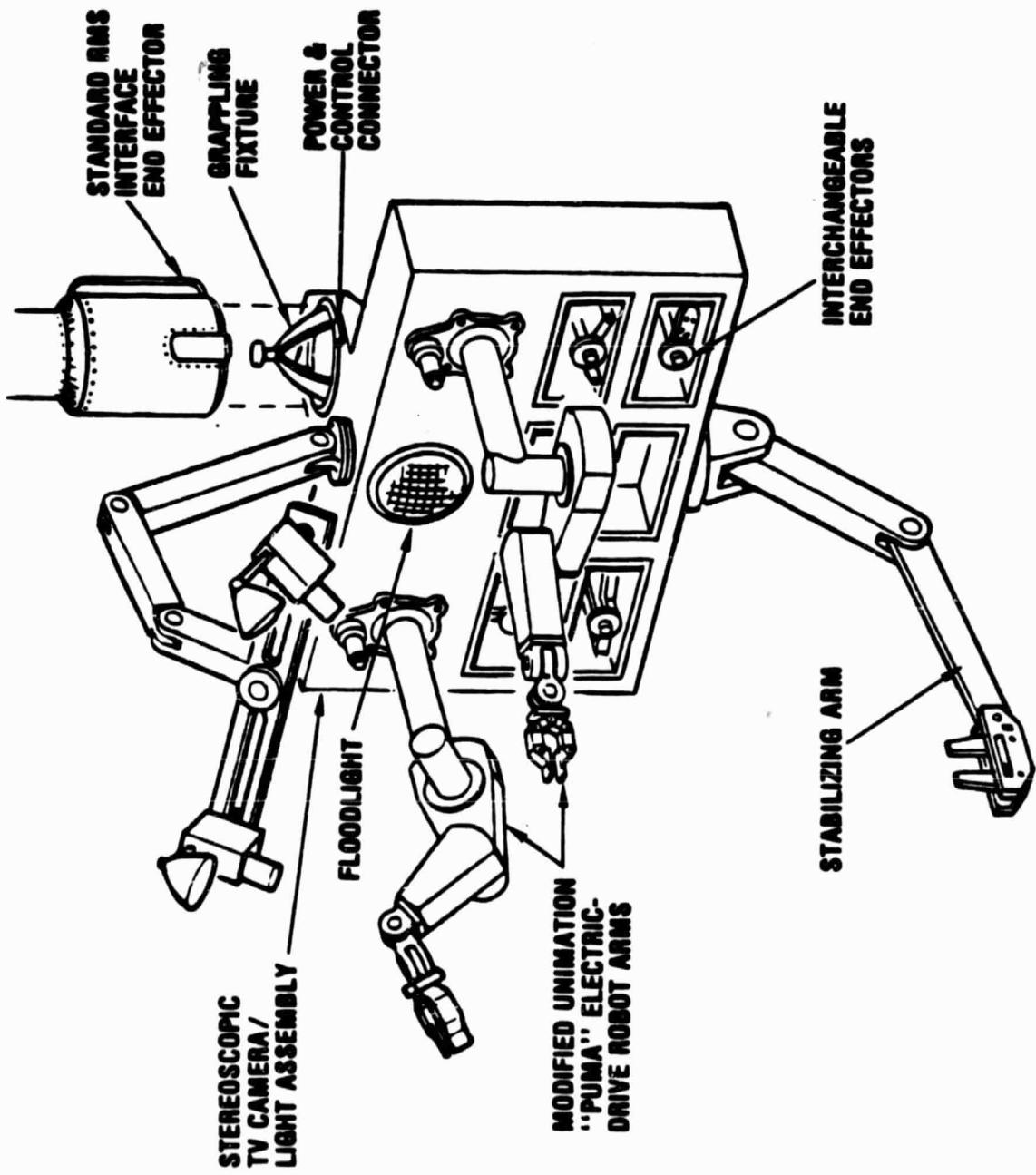
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AUTOMATION AND ROBOTICS

RMS END EFFECTOR

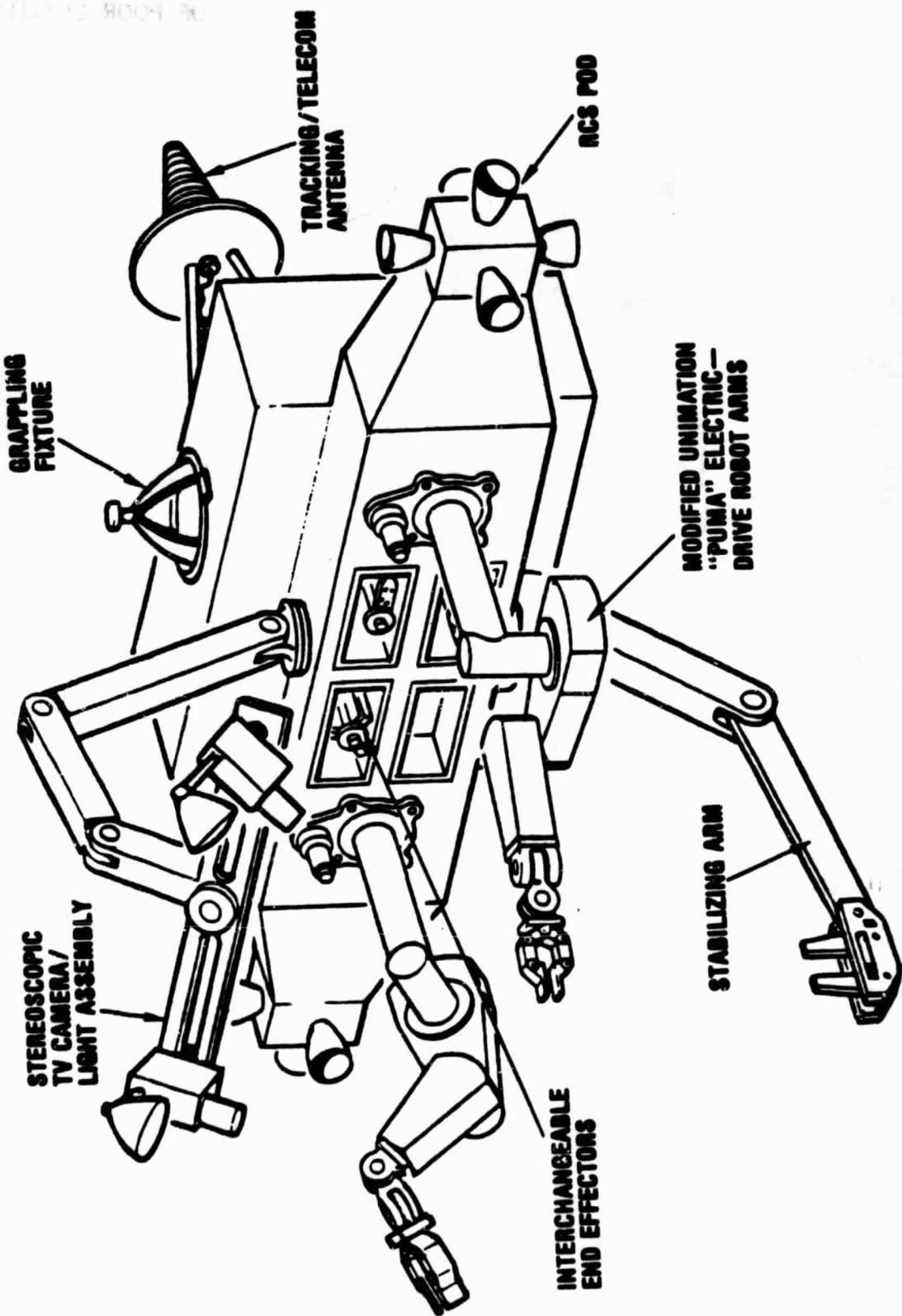
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AUTOMATION AND ROBOTICS

FREE FLYER

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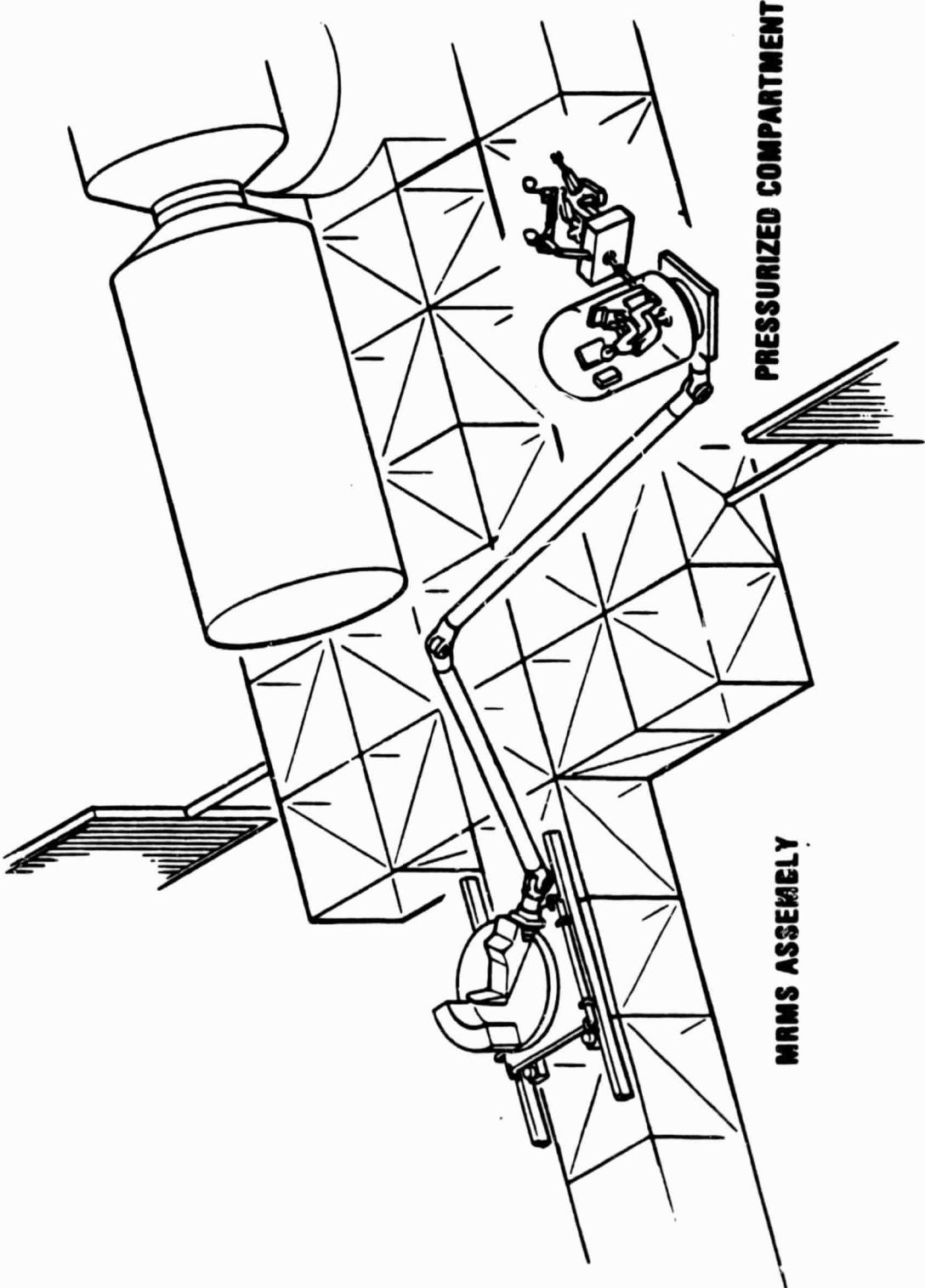


AUTOMATION AND ROBOTICS

MAN-IN-THE-BUBBLE

109

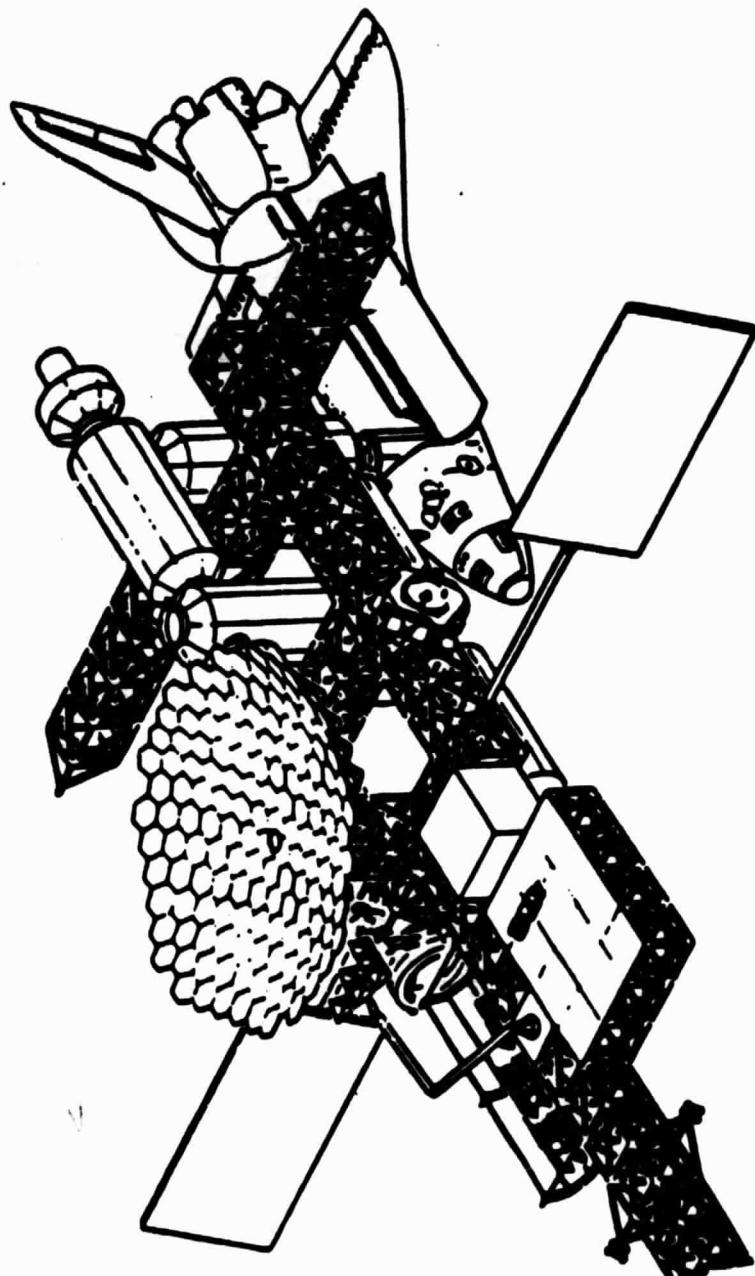
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LDR MIRROR-SET BACK-UP STRUCTURE ASSEMBLY

1 3009 JAN 1970
YTLAUS 8004 70

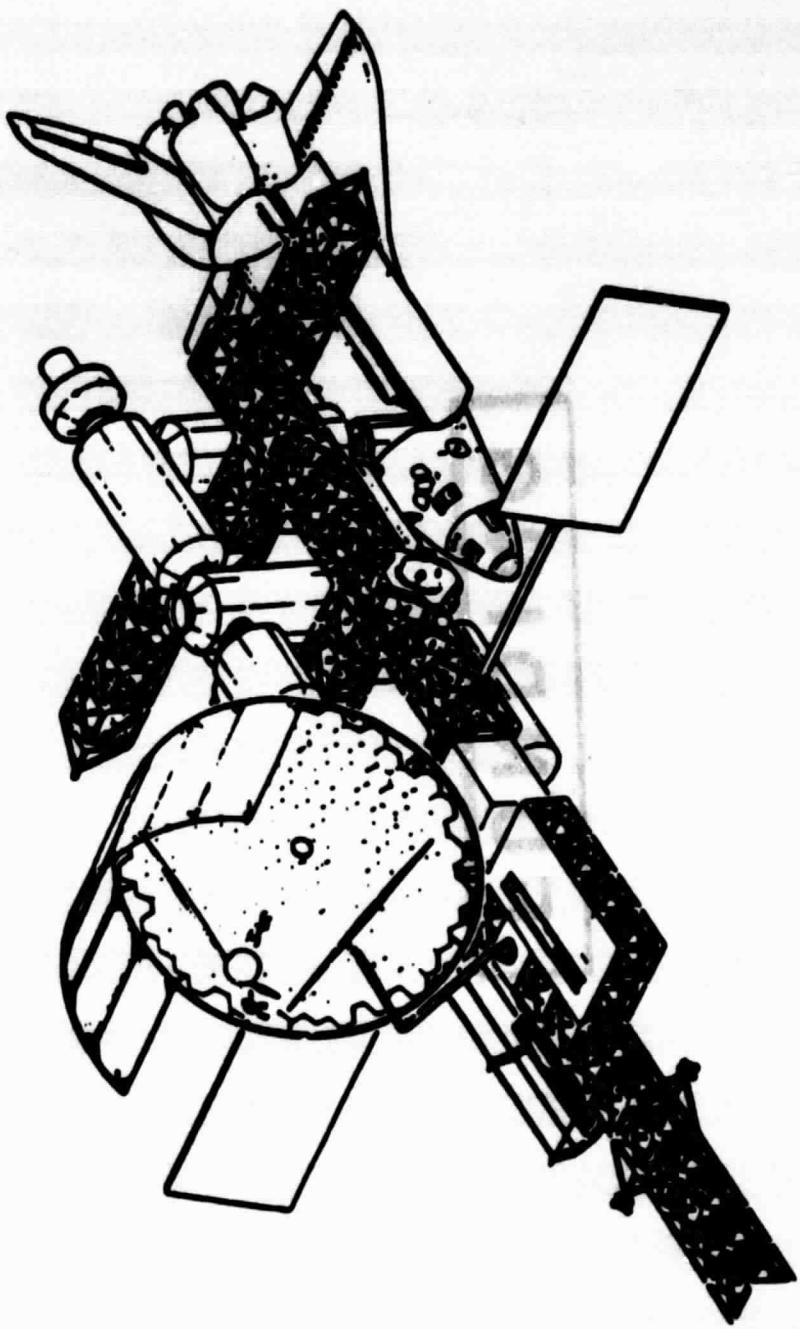
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**LARGE TELESCOPE CONSTRUCTION ON
SPACE STATION**

111

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OF 6000 COPIES

FUNDING

NO MORTGAGE CONVERSION
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FY 85
UTILIZATION ACTIVITIES

FY 85
UTILIZATION ACTIVITIES

FY 85 ACTIVITIES

- EXPERIMENT REQUIREMENT STUDIES
- NASA REVIEW
- BATTELLE STUDY
- USRA STUDY
- INDUSTRY VISITS

**FOCUSSED TO GENERATE REALISTIC TECHNOLOGY
DATA BASE**

NASA REVIEW

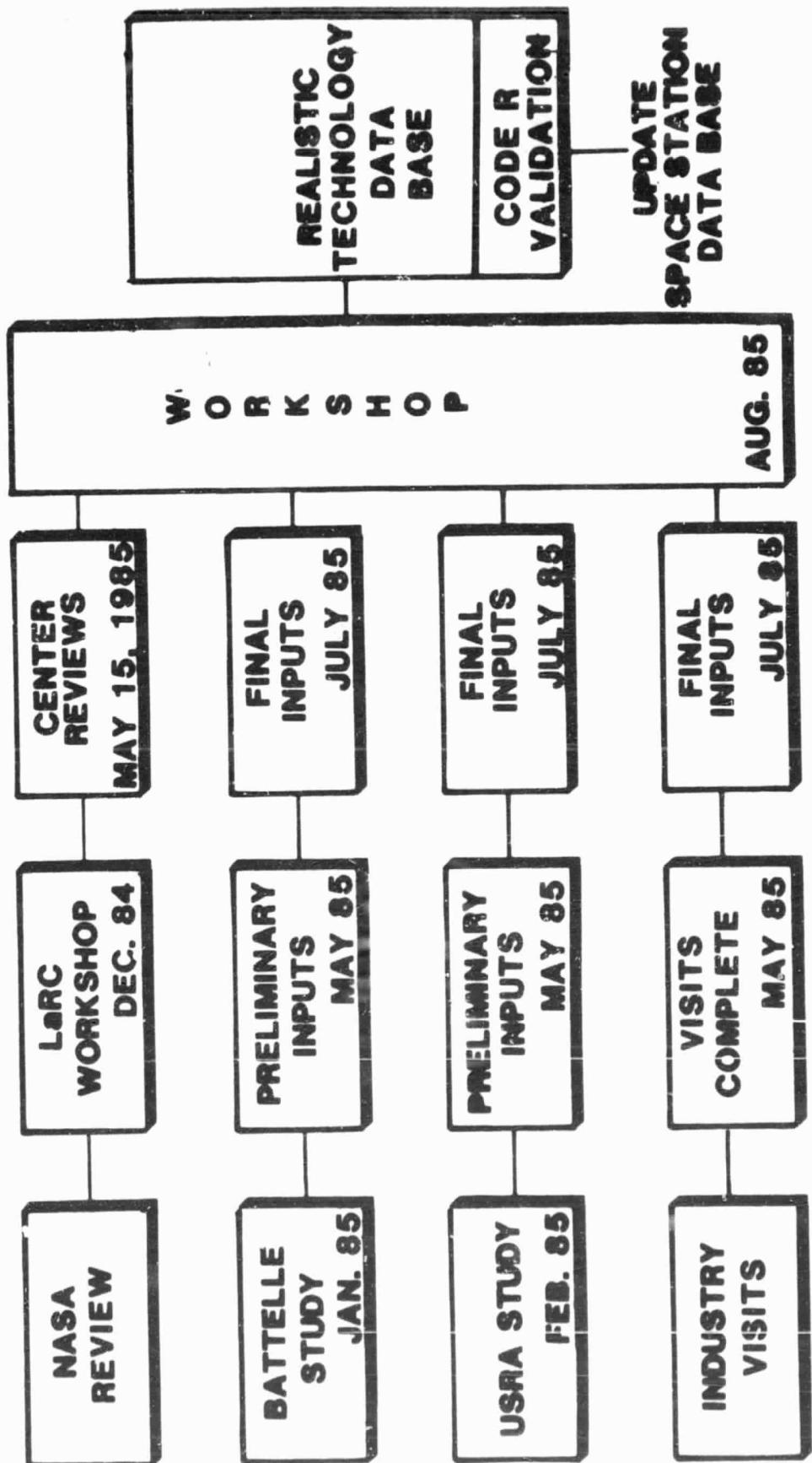
- LaRC WORKSHOP HELD DECEMBER 1984
- EACH CENTER REQUESTED TO:
 - Evaluate
 - Prioritize
 - Time-Phase
- EXISTING DATA BASE
- EACH CENTER REQUESTED TO IDENTIFY TECHNICAL Voids AND NEW EXPERIMENTS
- CENTER INPUT DUE MAY 15, 1985

BATTELLE STUDY

- 6 MONTH/\$135K/LORC
- CONTRACT INITIATED JANUARY 1985
- INITIAL REVIEW HELD MARCH 18, 1985
- SECOND REVIEW HELD MAY 1, 1985
- FINAL REVIEW SCHEDULED JULY 15, 1985
- PRODUCTS
 - ASSESSMENT OF EXISTING DATA BASE
 - IDENTIFICATION OF SPACE TECHNOLOGY OBJECTIVES
 - IDENTIFICATION AND DEFINITION OF R&T FACILITY EXPERIMENTS
 - COMPILEDATION OF TIME-PHASSED R&T FACILITY EXPERIMENTS

INTEGRATED ACTIVITIES

120

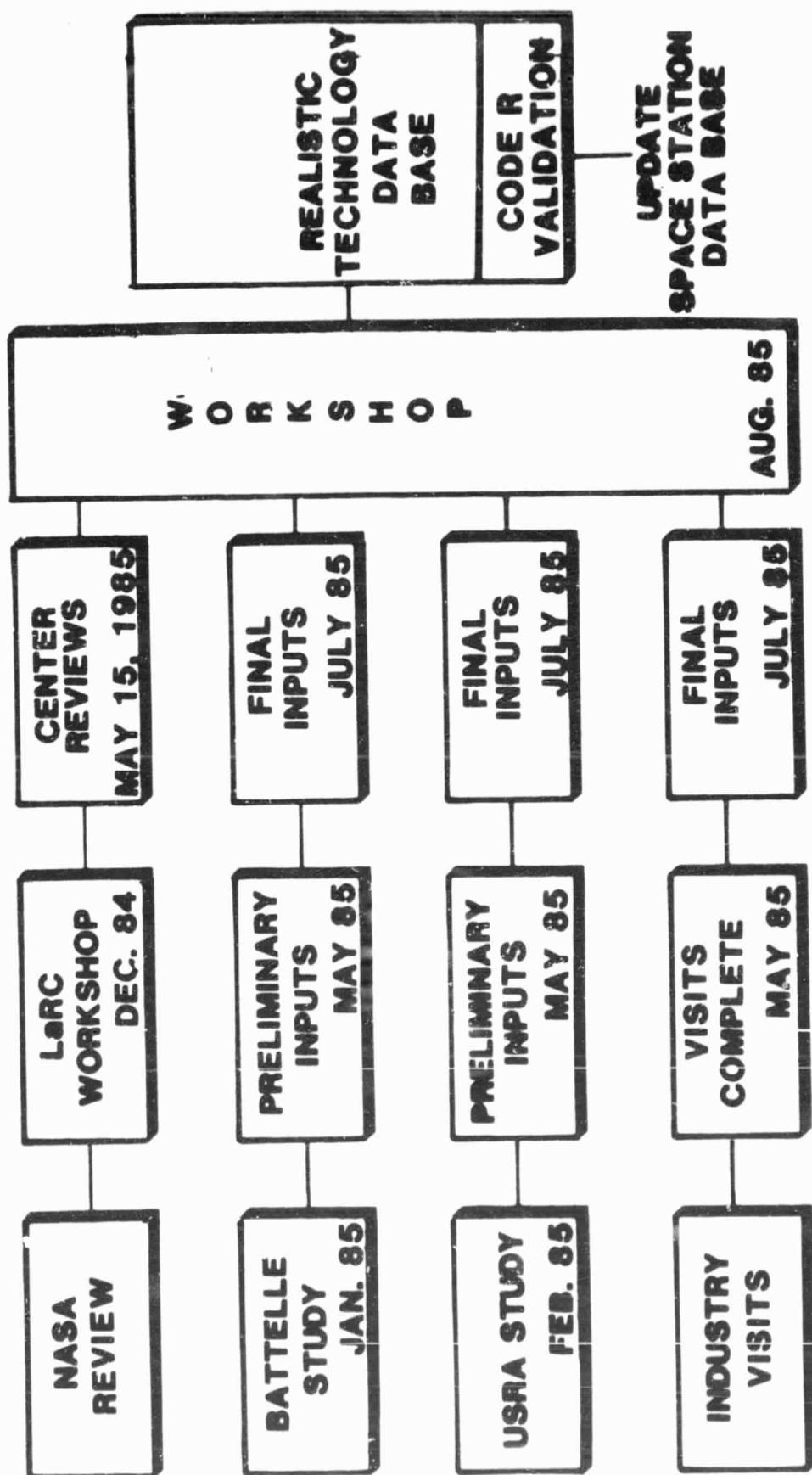


INDUSTRY VISITS

BOEING	FEBRUARY 11, 1985
LOCKHEED	FEBRUARY 12, 1985
ROCKWELL	MAY 29, 1985
TRW	MAY 30, 1985
MCDONNELL DOUGLAS	MAY 28, 1985
GENERAL DYNAMICS/CONVAIR	
MARTIN MARIETTA	
GRUMMAN	
GENERAL ELECTRIC	
RCA	
HARRIS CORP.	MARCH 8, 1985

INTEGRATED ACTIVITIES

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FY 86
TECHNOLOGY
UTILIZATION ACTIVITIES

FY 86 ACTIVITIES

- NEW EXPERIMENT ACCOMMODATION STUDIES
- HIGH PRIORITY EXPERIMENT ACCOMMODATION STUDIES
- TIME-PHASED MISSION MODEL

NEW EXPERIMENT ACCOMMODATION STUDIES

- APPROXIMATELY 10 EXPERIMENTS
- \$500K
- ALL CENTERS
- PRODUCTS
 - SKETCH OF EXPERIMENT
 - FUNCTIONAL DIAGRAM
 - LIST OF EXPERIMENTS
 - REQUIREMENTS FOR DATA BASE
- JULY 1986 COMPLETION DATE

HIGH PRIORITY EXPERIMENT ACCOMMODATION

STUDIES

- SELECT EXPERIMENTS THAT ARE MISSION DRIVERS
- 6-8 EXPERIMENTS
- \$400K
- SELECTED CENTER
- JANUARY 1986 COMPLETION DATE

TIME-PHASED MISSION MODEL

- IDENTIFY RESEARCH CLUSTERS
- TIME-PHASE LIST OF EXPERIMENTS
- GENERATE HISTOGRAM OF FUNCTIONAL REQUIREMENTS
- DEFINE FACILITY TO ACCOMMODATE REQUIREMENTS

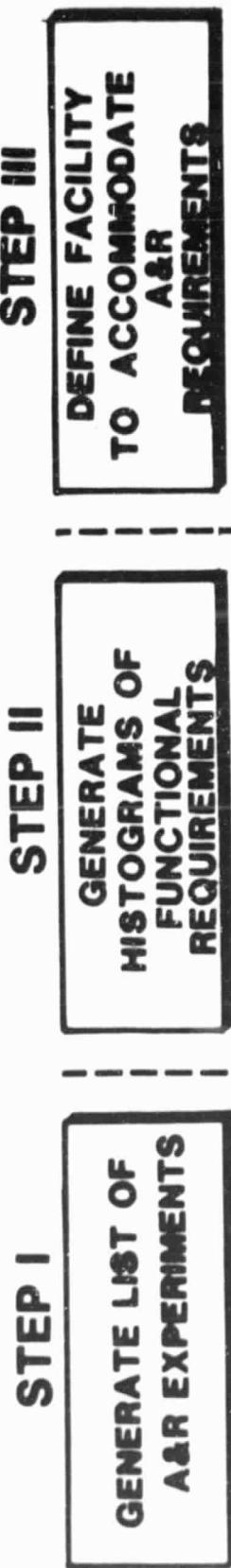
PROPOSED RESEARCH CLUSTERS

- **LARGE FLEXIBLE STRUCTURES**
- **AUTOMATION AND ROBOTICS**
- **IN-SPACE CONTAMINATION/ENVIRONMENTAL EFFECTS**
- **FLUID BEHAVIOR AND MANAGEMENT.**

AUTOMATION AND ROBOTICS

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1. ADVANCED END EFFECTORS
2. ADVANCED SENSORS
- 3.
- 4.
- 5.

EXAMPLE

RECOMMENDATIONS

RECOMMENDATIONS

FORM "PETER BANKS" TYPE TECHNOLOGY
USER COMMITTEE

Stanley Weiss, Lockheed

Industrial Considerations for Space Station Research and Technology

- Unique environment to expand general engineering knowledge
- Space applications
- Terrestrial applications
- Fundamental data bases
- Laboratory data
- Proof of concepts
- Terrestrial process modeling
- Space processes and manufacturing
- The space station support facility
- Incentives to industry use
- Limits to our plans of today

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Presentation to

Aeronautics and Science Engineering Board

In-Space Research and Technology Meeting

**Potential Industrial Uses
of Space Station**

**Langley Research Center
May 1985**

**E. G. Cole
Space Station Systems Division**

 **Rockwell International
Space Station Systems Division**

WHAT WE WILL COVER TODAY



- RESEARCH APPLICATIONS
- TECHNOLOGY DEVELOPMENTS
- MAJOR ISSUE — SERVICE COSTS
- MISSION EXAMPLES
- SUMMARY



Rockwell International
Space Station Systems Division

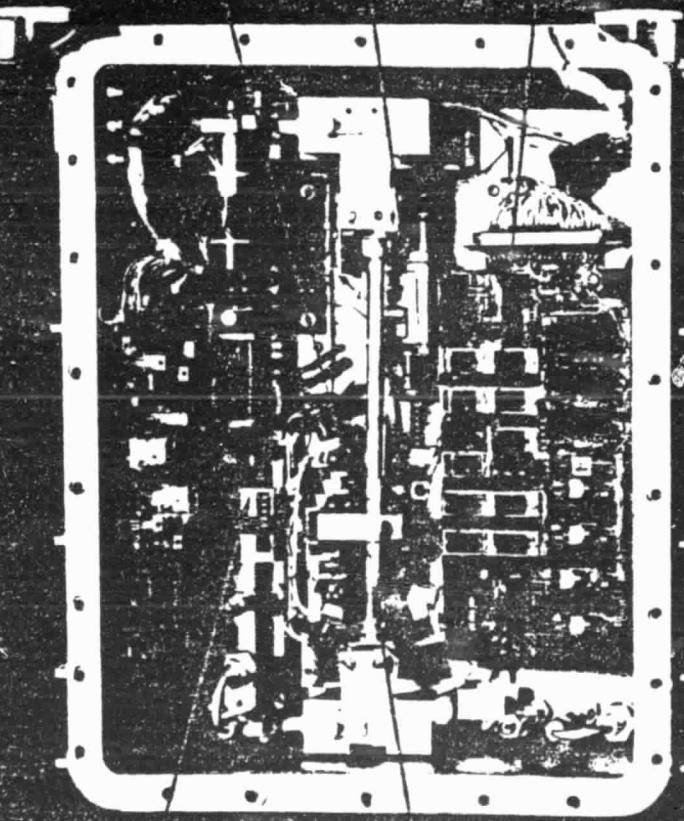
MAJORITY OF INDUSTRY APPLICATIONS WILL BE SMALL SCALE



RESEARCH & TECHNOLOGY APPLICATION:

- COMPANY SPONSORED IR&D EXPERIMENTS
- 3 DIMENSIONAL HEAT PIPE DESIGNS
- SMALL SENSOR SYSTEM DEVELOPMENT
- PILOT PRODUCTION FACILITIES
- TECHNOLOGY DEMONSTRATION MISSIONS FOR
NEXT GENERATION SPACE MISSIONS

FEA FLOAT ZONE CONFIGURATION



HEATER TRANSPORT
BIDIRECTIONAL
0.5 - 10 IN./HR
0.5 IN./MIN SLEW

SAMPLE CONTAINER
8.5 IN. LONG
0.65 IN. DIA

SAMPLE
0.4 IN. DIA

HEATER
100W

GAS RESERVOIR
ARGON - 2 PSI

DATA DISPLAY MODULE
TIME, SEC
HEATER POWER, W
HEATER POSITION, IN.
HEATER RATE, μ IN./SEC
TEMPERATURES (4), °C

FLUID EXPERIMENT APPARATUS IS BASIC AND APPLIED RESEARCH TOOL



USES

- FLOAT ZONE PROCESSING
- MIX GASES, LIQUIDS, & SOLIDS
- GENERAL LIQUID CHEMISTRY
- FLUID PHYSICS
- BIOLOGICAL CELL CULTURING

CHARACTERISTICS

- MASS: 12 KG
- VOLUME: .033 METER³
- POWER: 100-1000 WATTS
 - THERMAL DISSIPATION: 100-1000 WATTS?
- IVA HOURS PER EXPERIMENT: 1 HR/EXPERIMENT
- EXPERIMENT DURATION: 4-8 HRS AVERAGE



Rockwell International
Space Station Systems Division

TECHNOLOGY DEMONSTRATORS FOR FUTURE MISSIONS



- LUNAR COLONIES & MANNED MISSIONS TO MARS WILL REQUIRE LONG TERM DURATION DEMONSTRATIONS
- REQUIRES DEVELOPMENT OF CLOSED & REGENERATIVE TYPE SUB-SYSTEMS
 - CLOSED ECOLOGY SYSTEMS
 - CLOSED O₂ SYSTEMS
 - ADVANCED TWO PHASE SEPARATION SYSTEMS
- LONG TERM VACUUM EXPOSURE OF TYPICAL ORUS IS NECESSARY
 - FLUID PUMPS, GAUGING, INSTRUMENTS, STORAGE TANKS, INSULATION, ETC.
 - COMPONENT & ASSEMBLY – TESTING CAN BE DONE ON SPACE STATION



LARGE ANTENNA ASSEMBLY AND PERFORMANCE DEMONSTRATION



1. TECHNOLOGY DEMONSTRATION —

ASSEMBLY OF LARGE STRUCTURE IN SPACE

2. SIZE 25 m X 25 m

3. POWER

A.C.

OPERATING (kW) = 1 kW

HR/DAY = 6

PEAK (kW) = 1.5

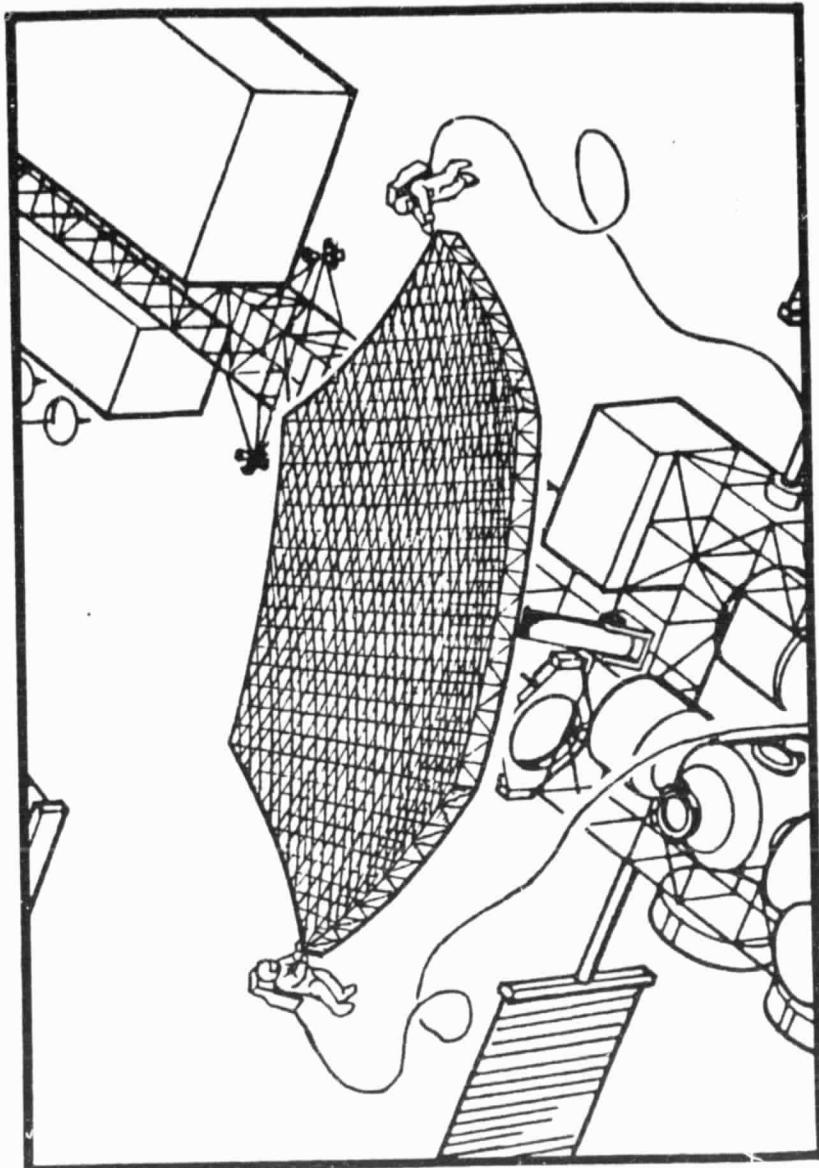
HR/DAY = 1

IVA — 100 MAN-HOUR

EVA — 120 MAN-HOUR

PERIOD — 33 DAYS

LAUNCH MASS = 2500 KG



Rockwell International
Space Station Systems Division

MAJOR INDUSTRIAL USE ISSUE



WHAT WILL IT COST TO USE?

NASA MUST MAKE SOME INDICATION OF
USER COST TO DEVELOP A CONSTITUENCY
PRIOR TO PHASE C, D BUDGET REQUEST

CANDIDATE SERVICES ARE:

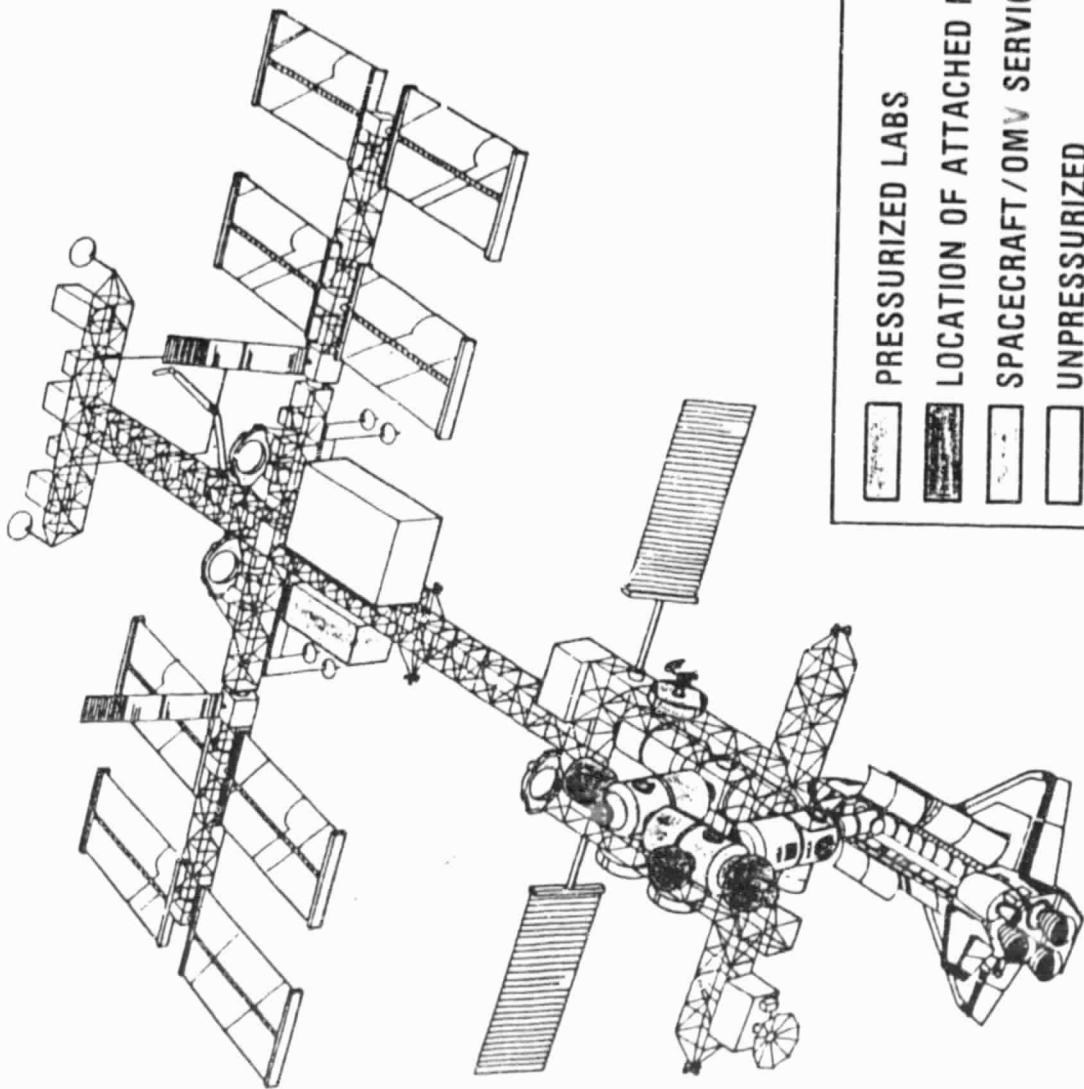


- PERSON-HOURS (IVA)
- PERSON-HOURS (EVA)
- POWER/ THERMAL — kW
- SPACECRAFT/OMV SERVICE FACILITY RESIDENCE —
FACILITY-DAYS
- PAYLOAD RESIDENCE
- INSIDE PRESSURIZED LABORATORY — VOLUME-DAYS
(METER³-DAYS)
- ATTACHED PRESSURIZED MODULE — PORT-DAYS
- UNPRESSURIZED BAY ATTACHMENT — BAY-DAYS



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LOCATION OF PAYLOAD RESIDENCES



ORIGINAL PAGE IS
OF POOR QUALITY

STRAWMAN APPROACH DEVELOPED



- SERVICE COSTS

$$\bullet \text{COSTS} = \frac{[\text{VALUE DISTRIBUTION FACTOR}] \times [\text{RECOVERABLE DAILY COST}]}{[\text{SERVICE CAPACITY}]}$$

- VALUE DISTRIBUTION FACTOR

- USE INVESTMENT COSTS AS INDICATION OF SERVICE VALUE
- ASSIGN SUBSYSTEM COSTS TO SERVICES — COST RATIO EQUATES TO VALUE RATIO
- SECONDARY BIAS FOR SPARES, LOGISTICS, & FACILITY POWER/TERMAL
- RECOVERABLE DAILY COST → FUNCTION OF NASA CHARGE POLICY
- SERVICE CAPACITY — USED NASA RFP — C-4 SYSTEM REQUIREMENTS



SERVICE VALUE DISTRIBUTION FACTORS ARE



SPACE
STATION

SERVICE

DAILY RECOVERABLE COST

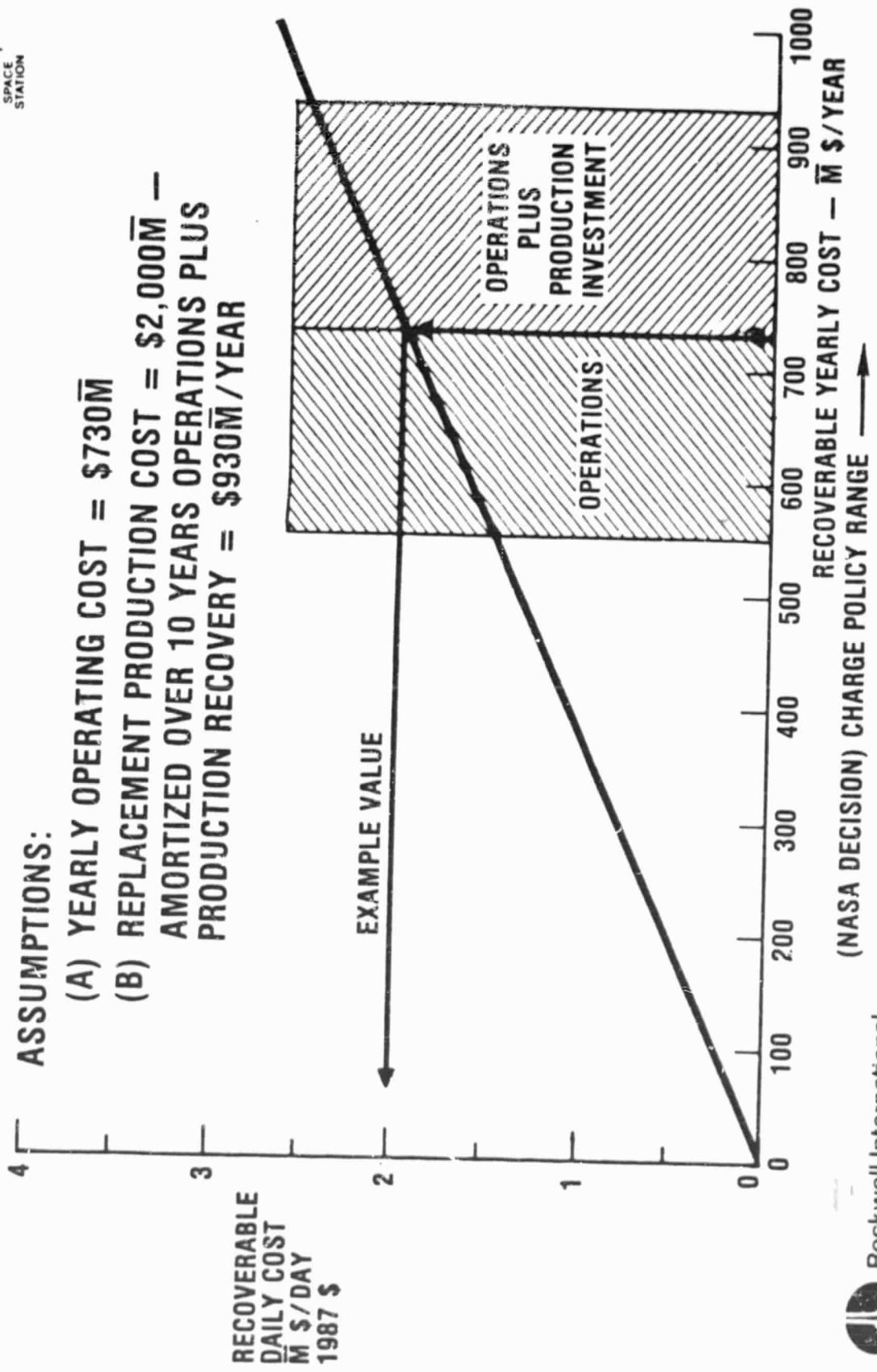
• IVA PERSON-HOUR	0.322
• EVA PERSON-HOUR	1.67 IVA PLUS EVA CONSUMABLES
• POWER/THERMAL (PAYLOAD)	0.228
• SPACECRAFT/OMV	0.022
• SERVICE FACILITY RESIDENCE	
• PAYLOAD RESIDENCE	
• PRESSURIZED LABORATORIES	0.184
• ATTACHED PRESSURIZED MODULES	0.120
• UNPRESSURIZED ATTACHMENT	0.124

NASA CHARGE POLICY WILL DETERMINE RECOVERABLE DAILY COST



ASSUMPTIONS:

- (A) YEARLY OPERATING COST = \$730M
- (B) REPLACEMENT PRODUCTION COST = \$2,000M — AMORTIZED OVER 10 YEARS OPERATIONS PLUS PRODUCTION RECOVERY = \$930M/YEAR



Space Station Systems Division

SERVICE CAPACITY AND COSTS ARE



SPACE
STATION

SERVICE	CAPACITY	SERVICE COSTS AT \$2M/DAY
• IVA CREW	72 PERSON-HOURS/DAY	\$8,940/PERSON-HOUR
• EVA CREW	6 HOURS/DAY NOMINAL MAX 80 HOURS/WEEK	\$67,000/EVA-HOUR
• POWER / THERMAL	75 kW — TOTAL 54 kW — PAYLOADS	\$8,370/kW-DAY
• SPACECRAFT / OMV RESIDENCE	2 LOCATIONS	\$22,000/STATION-DAY
• PAYLOAD RESIDENCE		
• PRESSURIZED LAB	246 METERS ³	\$1,500/M ³ -DAY
• ATTACHED MODULE	12 PORTS	\$20,000/PORT-DAY
• UNPRESSURIZED ATTACHMENT	46 BAYS (9 FT x 9 FT)	\$5,390/BAY-DAY

STANDARD STS TRANSPORTATION COSTS ARE NEEDED



CURRENT ASSUMPTIONS

- PERFORMANCE 59,103 LB -- 270 NMI 28.5°
- DOCKING TUNNEL 3,000 LB -- NEEDS 7 FT
- LOAD FACTOR -- 0.90
- USE 51,000 LB FOR WEIGHT COSTS
- USE 53 FT FOR LENGTH COSTS
- COST/FLIGHT = \$103M (1987 DOLLARS)

**COST PER POUND ~ \$2,020/LB
COST PER FOOT-LENGTH ~ \$1.94M/FOOT**

SMALL SCALE EXPERIMENT PROGRAM COSTS



SERVICES

MISSION: FEA PLUS 90 DAYS OF EXPERIMENTS

MASS — FEA = 12 KILOGRAMS
EXPERIMENTS = 90 KILOGRAMS

DURATION: 90 EXPERIMENTS IN 90 DAYS — EXPERIMENTS
CYCLE = 6 HOURS

POWER: 100 — 1000 WATTS

RESIDENCE: $0.033 \text{ m}^3 \times 2.8 = 0.0924 \text{ m}^3$

CREW: 1 HR/EXPERIMENTS

COSTS

TRANSPORTATION	\$0.45M
STATION SERVICES	<hr/> $1.57M$
	\$2.02M

LARGE ANTENNA TRANSPORTATION AND STATION COSTS



SERVICES

- MISSION DURATION: 20 DAYS
- CREW: IVA — 100 HRS
EVA — 120 HRS
- POWER: 1 kW
- RESIDENCE: UNPRESSURIZED ~3 BAYS
- MASS: 2800 KGM ~HARDWARE $\approx \$125\bar{M}$

COSTS

• TRANSPORTATION	\$11.0 \bar{M}
• STATION SERVICE	$\frac{9.5\bar{M}}{\$20.5\bar{M}}$



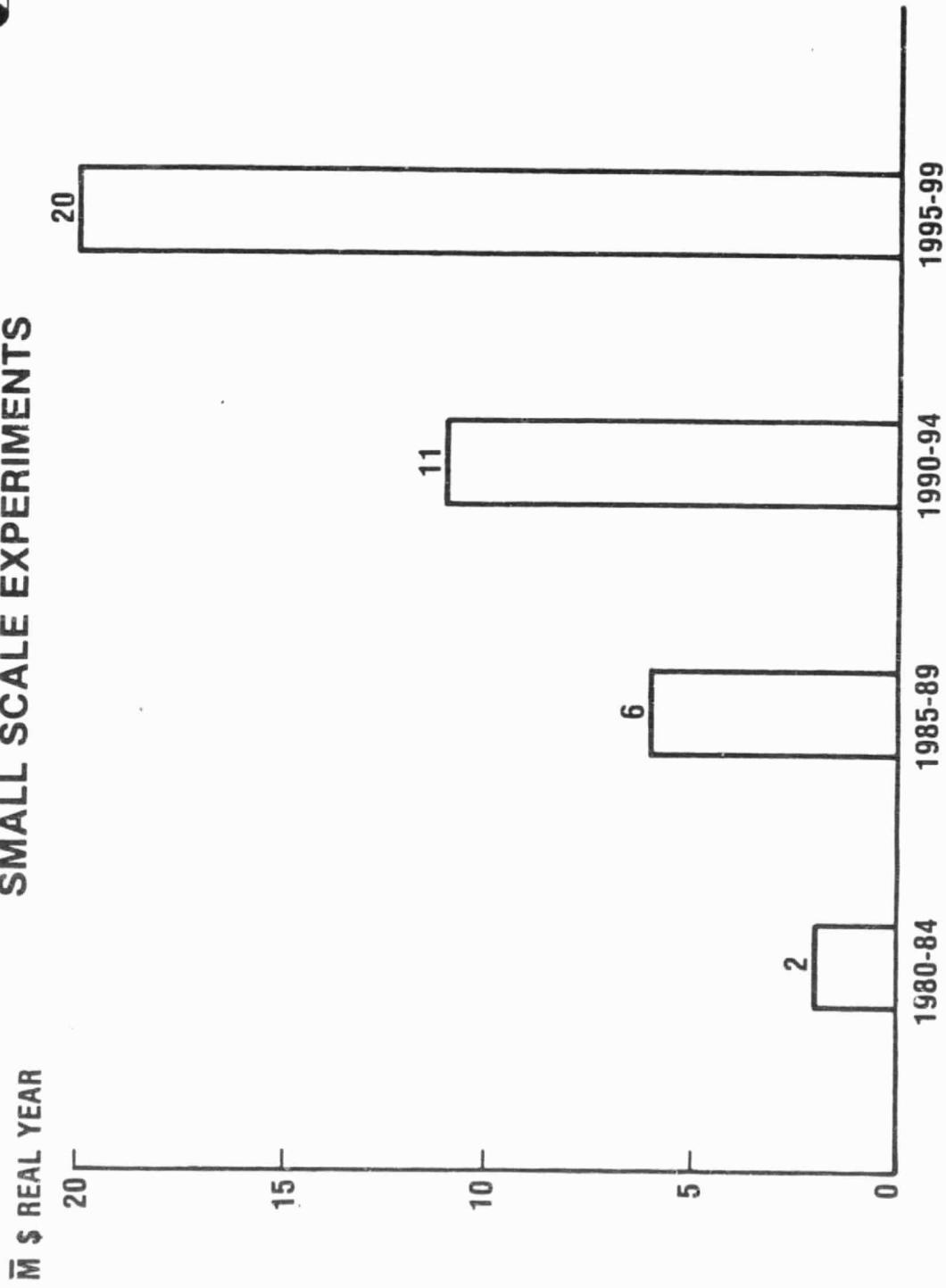
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POTENTIAL IN-SPACE R&D MARKET



SMALL SCALE EXPERIMENTS



150

SUMMARY



SPACE
STATION

- THERE ARE VIABLE INDUSTRIAL APPLICATIONS
- SERVICE COSTS — MAJOR INFLUENCE
- MARKET WILL GROW



UNIVERSITY ROLE IN SPACE STATION R&T
PROF. L. R. YOUNG

1. RESEARCH

- o INNOVATIVE
- o HIGH RISK
- o BRAIN POWER INTENSIVE
- o NOT REQUIRING LARGE FACILITIES

EXAMPLES

- o FLUID MECHANICS - 0-6 FLUID BEHAVIOR
- o CONTROL OF FLEXIBLE STRUCTURES
- o ADVANCED CLOSED LOOP LIFE SUPPORT SYSTEMS
- o ARTIFICIAL INTELLIGENCE

2. EDUCATION AND TRAINING

SPACE ENGINEERING:

- o FUNDAMENTAL DISCIPLINES
 - E.g. RARIFIED GAS ATMOSPHERE, RADIATION VS.
CONDUCTIVE HEAT TRANSFER
- o ADVANCED SPACE ENGINEERING COURSES
 - E.g. SPACECRAFT COMMUNICATIONS, MANNED SPACECRAFT
ENGINEERING (INCLUDING LIFE SUPPORT),
O-G FLUIDS, COMBUSTION, SPACE POWER
GENERATION, SPACE MATERIAL

3. HOW CAN NASA HELP?

SUPPORT FOR PRE-DOCTORAL TRAINEES AND CURRICULUM DEVELOPMENT

SUGGESTIONS FOR NASA SPACE ENGINEERING FELLOWS:

- (1) SPACE ENGINEERING COURSE CURRICULUM
- (2) ONE YEAR AS A T.A. - WORKING ON COURSE DEVELOPMENT OF A NEW SPACE ENGINEERING COURSE (HOME PROBLEMS, LAB EXERCISES, ETC.)
- (3) ENCOURAGE (OR REQUIRE) MINIMUM OF ONE SUMMER AT A NASA RESEARCH CENTER (PERMIT SOME RESEARCH WORK AT A CENTER WHERE UNIQUE FACILITIES EXISTS)

3. HOW CAN NASA HELP? (CONT'D.)

- (4) CONSIDER FORGIVABLE LOANS TO ENSURE GRADUATES STAY IN SPACE FIELD FOR AT LEAST TWO YEARS
- (5) FACULTY CURRICULUM DEVELOPMENT FUNDS (DEMAND NEW COURSE NOTES FOR NEW COURSES)
- (6) OFFER OF NASA SUPPORTED TWO WEEK SUMMER COURSES AFTER TWO YEARS TO SPREAD THE WORD

RECOMMENDATION:

NASA/OAST IS ENCOURAGED TO ESTABLISH A UNIVERSITY TRAINERSHIP

IN SPACE ENGINEERING - PRE-DOCTORAL PROGRAMS TO EDUCATE THE
FUTURE LEADERS FOR RESEARCH AND TECHNOLOGY IN SPACE.

EMPHASIS IS TO BE PLACED ON SUPPORT OF PRE-DOCTORAL FELLOWS
AND CURRICULUM DEVELOPMENT. TIES TO NASA CENTERS DURING
THE TRAINING PERIOD ARE TO BE ENCOURAGED.

APPENDIX C**NASA/Industry Relationships**

Submission by Donald P. Hearth

C-1	<u>NASA's Space R&T Support of Industry and DOD: Obstacles and Recommended Actions.</u>	161
C-2	Memorandum to NASA Center Directors from NASA Administrator.	179
C-3	<u>Study of U.S. Industry Use of NASA In-Space Facilities for Technology Experiments.</u>	181

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Appendix C-1

FEB. 24, 1984

NASA'S SPACE R&T SUPPORT OF
INDUSTRY AND DOD

OBSTACLES AND RECOMMENDED ACTIONS

NASA SUPPORT OF SPACE INDUSTRY

QUESTIONS

- WHAT ARE THE OBSTACLES TO NASA SUPPORTING THE SPACE INDUSTRY IN A MANNER SIMILAR TO THE AGENCY'S SUPPORT OF THE AERO INDUSTRY?
- WHAT ACTIONS CAN BE TAKEN TO OVERCOME THE OBSTACLES?

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BOB WALQUIST -----	TRW; SSTAC CHR.

OVERVIEW

- MOST OBSTACLES DUE TO:
DIFFERENCE IN RELATIONSHIPS BECAUSE OF DIFFERENT EVOLUTION OF NACA/NASA
AND INDUSTRY GROUPS
- AERONAUTICS -- TECHNICAL COLLEAGUES
INDUSTRY IS NASA'S CUSTOMER
- SPACE -- NASA IS MISSION AGENCY
NASA IS INDUSTRY'S CUSTOMER

(DOD VIEWS SAME AS INDUSTRY'S)
- NASA CANNOT SUPPORT SPACE INDUSTRY EXACTLY AS IT DOES AERO INDUSTRY
- NASA CAN & SHOULD SUPPORT SPACE INDUSTRY MORE THAN IT DOES TODAY
REQUIRES ---- ACTIONS TO OVERCOME OBSTACLES
INCREASED SPACE R&T BUDGET

OBSTACLES

- FACILITIES
- CONFLICT OF INTEREST
- PROGRAM CONTENT/CENTERS OF EXCELLENCE
- COMMUNICATIONS AND MARKETING

OBSTACLE - FACILITIESSITUATION

- NASA HAS MANY UNIQUE AERO FACILITIES
SERVE AS MAGNETS TO INDUSTRY → NASA/INDUSTRY RELATIONSHIPS
RECOGNITION OF NASA CAPABILITY
IMPACT OF INDUSTRY ON NASA
PROGRAM
- NASA DOES NOT HAVE MANY UNIQUE SPACE FACILITIES
- INDUSTRY CONCERNED WITH NASA HAVING SPACE FLIGHT ASSEMBLY FACILITIES

ACTIONS

- NASA EXPLOIT UNIQUE SPACE FACILITIES
IN PARTICULAR -- MEANS TO CONDUCT EXPERIMENTS IN SPACE
FACILITATE INDUSTRY ACCESS
ASSIGN LEADERSHIP TO NASA'S RESEARCH ELEMENTS

OBSTACLE - CONFLICT OF INTERESTSITUATION

- AERO -- ONLY NASA ROLE IS R&T
- SPACE -- MAJOR NASA ROLE IS PROJECTS
- SOME NASA CENTERS COMPETE WITH SPACE INDUSTRY FOR SPACE FLIGHT HARDWARE
- NASA SPACE R&T DIRECTED AT NASA MISSIONS
DOES NOT ADEQUATELY REFLECT NON-NASA MISSIONS
- LARGE PORTION OF SPACE R&T AT NASA MISSION CENTERS

ACTIONS

- NASA ADMINISTRATOR STATEMENT ON NON-NASA MISSION R&T SUPPORT ROLE
IN SELECTIVE TECHNOLOGIES
SIMILAR TO NASA'S AERO R&T ROLE
- DOD SUPPORT NASA'S ROLE & COMMUNICATE TO SPACE CONTRACTORS
- NASA CENTERS CLOSELY MONITOR I&D PROGRAMS
- NASA SPACE R&T PRIMARILY AT RESEARCH CENTERS
RESEARCH CENTERS LIMIT SPACE PROJECT RESPONSIBILITIES

OBSTACLE - PROGRAM CONTENT/CENTERS OF EXCELLENCE

SITUATION

- PERCEPTIONS OF DOD & INDUSTRY:
 - AERO R&T -- NASA NATIONAL LEADER
 - SPACE R&T -- NASA FOLLOWER IN TECHNOLOGIES FOR NON-NASA MISSIONS
- NASA CANNOT/SHOULD NOT ATTEMPT TO BE NATIONAL LEADER IN ALL TECHNOLOGIES FOR NON-NASA MISSIONS
- NASA CAN/SHOULD BE NATIONAL LEADER IN SELECTIVE CASES
- TOO LIBERAL IN USE OF TERM "CENTER OF EXCELLENCE"
- SPACE R&T RESOURCES SPREAD ACROSS TOO MANY NASA CENTERS

ACTIONS

- NASA (WITH DOD & INDUSTRY) SELECT TECHNOLOGIES FOR NASA LEADERSHIP INCLUDE MOST TECHNOLOGIES IN NASA PROGRAM BUT, CONCENTRATE ON "EMERGING" TECHNOLOGIES (LEAP FROG POTENTIAL)
- BE SELECTIVE IN USE OF "CENTER OF EXCELLENCE"
- LARGER INDUSTRY & DOD IMPACT ON CONTENT OF NASA'S SPACE R&T PROGRAM (ROLE OF STAC SUBCOMMITTEES?)
- DEVELOP CO-OP PROGRAMS WITH SPACE INDUSTRY AS WITH AERO INDUSTRY

OBSTACLE - COMMUNICATIONS AND MARKETING

SITUATION

- NEED IS GREATER IN SPACE THAN IN AERO
- NASA NOT AS EFFECTIVE IN SPACE R&T AS IT IS IN AERO R&T
- DISSEMINATION OF TECHNICAL ADVANCES FROM NASA FLIGHT MISSIONS NOT SUFFICIENT

ACTIONS

- NASA AGGRESSIVELY MARKET ITS SPACE R&T CAPABILITIES
- IMPROVE QUALITY OF NASA SPACE R&T CONFERENCES
- ATTRACT INDUSTRY TECHNOLOGISTS, NOT JUST MARKETING PEOPLE
- INCENTIVES FOR NASA MISSION TECHNOLOGISTS TO PUBLISH

FUNDING LEVEL FOR SPACE R&I

SITUATION

- NOT ON AGENDA - DISCUSSED ANYWAY
- GENERAL CONCLUSION - CURRENT LEVELS TOO LOW IF NASA TO PROVIDE SUPPORT TO NON-NASA MISSIONS CONSISTENT WITH RECOMMENDED

ACTIONS

ACTIONS

- SEEK "INNOVATIVE" FUNDING SOURCES (ANALOGY TO HIGHWAY TRUST FUND?)
- INCREASE BUDGET
TO SELECTIVELY BUILD IN HOUSE CAPABILITIES & OUT OF HOUSE
COMPONENTS OF NASA PROGRAM (INCLUDING UNIVERSITIES)

A BROADER ROLE FOR SPACE TECHNOLOGY

NASA POLICY

"IN TECHNOLOGY AREAS WHERE WE HAVE UNIQUE FACILITIES AND EXPERTISE TO OFFER, IT WILL BE NASA'S POLICY TO SUPPORT THE DOD AND THE SPACE INDUSTRY THROUGH COOPERATIVE R&T PROGRAMS JUST AS WE DO IN AERONAUTICS. THE NASA CHARTER CLEARLY SUPPORTS THAT ROLE."

"THERE IS ONE AREA WHERE I THINK WE CAN BE PARTICULARLY EFFECTIVE IN ESTABLISHING CLOSER TIES WITH THE INDUSTRY IN TECHNOLOGY DEVELOPMENT AND THAT IS IN THE USE OF THE SHUTTLE TO PROVIDE ACCESS FOR IN-SPACE EXPERIMENTS. FURTHERMORE, SUCH ACTIVITIES WILL ESTABLISH A WAY OF DOING BUSINESS THAT LEADS QUITE NATURALLY INTO USE OF THE SPACE STATION AS A RESEARCH CENTER IN SPACE FOR TECHNOLOGY AND ENGINEERING EXPERIMENTS IN ZERO GRAVITY."

JAMES BEGGS TO PROGRAM AA'S & CENTER DIRECTORS
APRIL 3, 1984

A BROADER ROLE FOR SPACE TECHNOLOGYACTIONS REQUESTED BY NASA ADMINISTRATOR

- INCREASE EMPHASIS ON IN-SPACE FLIGHT EXPERIMENTS
- INITIATE COOPERATIVE R&T PROGRAMS WITH INDUSTRY
- SELECT AREAS (WITH DOD AND INDUSTRY) FOR WHICH NASA SHOULD BE NATIONAL R&T LEADER

BEGGS APRIL 3, 1984, MEMO

NASA'S SUPPORT OF THE "SPACE INDUSTRY"¹

INTRODUCTION

For many years, the NACA/NASA Aeronautics R&T program has made sizeable contributions to the development of aviation in the United States. These contributions have arisen both from the application of NACA/NASA research by industry and from a close working relationship between industry and NACA/NASA. The situation in Space is significantly different. For many years, the NASA space flight program has been the dominant space flight program in the United States. Thus, the NASA Space R&T program quite naturally was directed at the Agency's future space missions. In recent years, however, the military and commercial space flight programs have grown to be larger than NASA's program. NASA's Space R&T, however,¹ has not responded to this "market" and does not support the Space Industry¹ as it does the Aeronautics Industry¹. This situation has lead to the following questions:

- 1) Should NASA support the Space Industry as it does the Aeronautics Industry?
- 2) Is the NASA Space R&T budget adequate to provide this support?
- 3) What are the obstacles (other than funding) to NASA providing such support and what might NASA do to overcome the obstacles?

The first and second questions were examined at the 1982 Woods Hole Summer Study conducted by the National Academy; in summary, the answers were "Yes" to the first question and "No" to the second. The third question was the subject of two meetings held with industry and university representatives in January 1984. This paper summarizes the January 1984 meetings.

OVERVIEW

There are significant "cultural" differences between Aeronautics and Space largely resulting from how NACA/NASA and the two industry groups have evolved. In the case of Aeronautics, NACA/NASA and the Industry developed very much as technical colleagues. In Space, however, the relationship has been one of NASA being a mission/contracting agency and the Space Industry being its contractors. For NASA to support the industry, both organizations must believe that industry is NASA's customer — while this is the common attitude in Aeronautics, it is not the attitude of either NASA or the industry in the case of Space. The NASA/DOD relationship in Space is also different than the relationship between NASA and DOD in Aeronautics. For over 60 years, the DOD has understood and has supported NASA's Aeronautics role. Thus, many cooperative Aeronautics programs exist between DOD and NASA, and DOD encourages their contractors to have close working relationships with NASA. The common attitude of DOD toward NASA's space role is similar to that of the Space Industry. Consequently, the DOD Space organizations have not encouraged

¹Includes DOD

their contractors to solicit technical support from NASA as have their Aeronautics colleagues in DOD.

This situation is exacerbated by the lack of a clear NASA statement on the Agency's role in providing R&T support to the Space industry for non-NASA missions. In addition, there is less willingness within the Space Industry, than there is in the Aeronautics Industry, to share technology between individual companies.

The cultural differences summarized above are the bases of many of the obstacles identified in the January 1984 meetings. The general view of the people attending these meetings is that NASA cannot expect to support the Space industry exactly as it does the Aeronautics industry. However, the attendees do believe that NASA can and should, in its relationships with the Space Industry, move much closer to the type of relationship it has with the Aeronautics industry. With an increase in NASA's Space R&T budget and with the actions outlined below, the meeting attendees believe that substantive progress can be realized in reaching this objective.

OBSTACLES AND ACTIONS²

• Facilities

The NASA Centers have many unique facilities for Aeronautics R&D. These serve as magnets to industry and have contributed significantly to the development of close NASA/industry relationships. This has, in turn, resulted in a recognition by the Aeronautics Industry of NASA's in-house capabilities, increased willingness/desire of the Aeronautics Industry to solicit and accept NASA's help during the R&D cycle, and a strong impact of the industry on the content of NASA's Aeronautics Program. On the other hand, most major Space Companies have their own facilities and rarely are dependent on NASA's Space facilities (exceptions include launch and atmospheric entry facilities). Thus, NASA does not generally have unique Space facilities to serve as magnets to Industry. This has deterred the development of the same type of NASA/Industry relationships in Space that have developed in Aeronautics. In addition, Industry is usually concerned with NASA building in-house facilities for the final assembly and test of space flight hardware.

Actions

- 1) NASA should better exploit those NASA space facilities that are unique. In particular, the capability of conducting in space experiments on the Shuttle and the Space Station for the development of technology for NASA, DOD, and the Space Industry should be fully exploited. NASA should manage the use of these "facilities" for this purpose much as it does its Aeronautics facilities. For example, the leadership on the use of in space facilities for

²Not in priority order.

technology experiments should be assigned to the research elements of NASA and all possible steps should be taken to make it worthwhile for experimenters from NASA, DOD, and the Industry to use them as national test facilities.

- Conflict of Interest

In Aeronautics, NASA's role is one of R&T which supports civil and military aviation; in Space, NASA has a major role in missions of its own and, in some cases, NASA Centers are viewed by Industry as competitors for space flight hardware. Consequently, a major portion of the NASA Space R&T is directed at its own missions and does not adequately reflect the DOD/Industry R&T needs for non-NASA missions. This is exacerbated by a significant portion of the NASA Space R&T being performed by NASA Centers which also have responsibilities for NASA Space missions and development programs.

Actions

- 2) The NASA Administrator should clearly state that NASA's role includes R&T support, in selected technologies, of the DOD and the Space Industry for non-NASA missions in a manner similar to the NASA role in Aeronautics.
- 3) The Office of the Secretary for Defense should support this NASA role in Space R&T, communicate its position to their contractors in the Space Industry, and actively encourage the development of technical relationships by DOD and its contractors with NASA.
- 4) The NASA Centers should closely monitor the IR&D programs of the Space Industry. This will provide NASA with an increased understanding of Industry's R&T programs and will send Industry the message that "NASA cares."
- 5) Space R&T should be primarily conducted in NASA's Research Centers; these Centers should emphasize their research roles in Space as they do in Aeronautics (for example, they should limit their space flight project management responsibilities).

- Program Content/Centers of Excellence

In Aeronautics, the predominant view at DOD and the Industry is that NASA R&T is a national leader. In Space, however, the predominant view of DOD and the Space Industry is that the NASA Space R&T is, in many cases, a follower to Industry R&T in those technologies which are applicable to non-NASA missions. It is felt that NASA cannot, and should not, be a Space R&T leader in all disciplines and systems applicable to non-NASA missions. However, NASA can be, and should be, a leader in selective disciplines and systems. In addition, NASA has been too liberal in the use of the term "Center of Excellence" and its Space R&T program is performed by too many NASA Centers for the resources available.

Actions

- 6) NASA, with the assistance of DOD and the Space Industry, should select technologies for which NASA should be the national R&T leader; where appropriate, NASA should concentrate on "emerging technologies" which will "leap frog" current space systems. In addition, NASA should aggressively pursue only those technologies unique to space which are not being accelerated by non aero-space applications. NASA should make its facility investments and resource allocation decisions consistent with these selections. It is recognized that NASA's Space R&T must include most Space related disciplines and systems. Nevertheless, NASA should not attempt to be a national Space R&T leader in all cases.
- 7) NASA should be very selective in citing an in-house NASA capability as a "Center of Excellence." Not all R&T capabilities at the NASA Centers need be considered "Centers of Excellence" and NASA Headquarters should, if the R&T is required, be supportive even of those Space R&T capabilities that are not identified as a "Center of Excellence."
- 8) The user segments of the DOD and the Space Industry should have a larger role in planning the content of the NASA Space R&T Program.
- 9) The NASA Centers engaged in Space R&T should develop cooperative programs and technical relations with the Space DOD and the Space Industry similar to what NASA has with the Aeronautics DOD and the Aeronautics Industry.

- Communications and Marketing

NASA does not effectively market its Space R&T and in-house space capabilities to that portion of the Space Industry which is predominantly engaged in commercial and military Space Programs. NASA does not have the magnet facilities in Space that it has in Aeronautics and the NASA/Industry relationship is different in Space than it is in Aeronautics. Thus, the need for NASA marketing its capabilities is greater in Space than it is in Aeronautics; yet, NASA is less effective in Space than it is in Aeronautics. Another factor is that a number of technology advances result from NASA Space Flight Projects conducted by NASA's Development Centers. Generally, these results are not disseminated to Industry as effectively as Aeronautical R&T results are disseminated.

Actions

- 10) NASA should aggressively market its Space R&T capabilities to the Space organizations of DOD and to the Space Industry. This requires in plant visits to Industry management and technologists.
- 11) The quality of NASA conferences on Space technology should be improved and specifically designed to attract the technologists from the Space Industry to attend the NASA conferences.
- 12) NASA should provide incentives to its space project technologists to transfer, on a timely basis, major technological advances to the Space Industry.

- Funding Level

While not an agenda item of the January 1984 meetings, the adequacy of the NASA Space R&T funding level was discussed. The general conclusion was that current levels are too low if NASA is to provide the support discussed above.

Actions

- 13) NASA should seek innovative sources of Space R&T funding that are separate from the annual budget cycle (example -- an analogy to the Highway Trust Fund?).
- 14) NASA should increase its Space R&T budget in order to selectively build up in-house capabilities and to increase the out-of-house components (including at the universities) of the in-house NASA programs.

PARTICIPANTS

Mac Adams ----- DOD, Formerly AVCO & NASA
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Ed Cortright ----- Formerly Lockheed & NASA
Don Fraser ----- Draper Labs; SSTAC Subcomm. Chr.
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John Hedgepeth ---- ASTRO; SSTAC Subcomm. Chr.
Dick Heppe ----- Lockheed; ASEB
Roy Jackson ----- Northrop, Formerly NASA
Jack Kerrebrock --- MIT, Formerly NASA
Art Mager ----- Formerly Aerospace; SAAC Chr.
Jerry Molitor ----- Hughes; SSTAC Subcomm. Chr.
Fritz Oder ----- Lockheed
Adrain O'Neal ----- McDonnell Douglas; SSTAC Subcomm. Chr.
Bob Seamans ----- MIT, Formerly Air Force & NASA
Joe Shea ----- Raytheon, Formerly NASA; ASEB Chr.
Roy Smelt ----- Formerly Lockheed
Bob Walquist ----- TRW; SSTAC Chr.



National Aeronautics and
Space Administration

Washington, D.C.
20546

Office of the Administrator

APR 3 1984

TO: Directors, NASA Field Installations
Director, Jet Propulsion Laboratory
Officials-in-Charge of Program Offices

FROM: A/Administrator

SUBJECT: A Broader Role for Space Technology

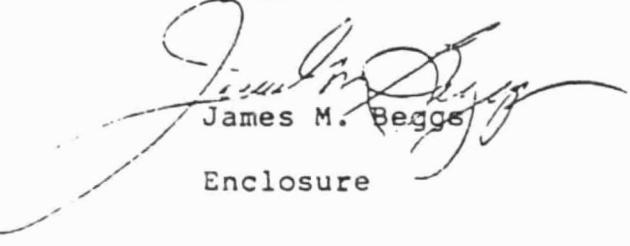
As you know, we have been seeking greater involvement and participation of industry and the university community in our Space Technology program. Recently, Don Hearth assembled a small group of national leaders of the aerospace community to explore some of the obstacles to NASA support of DOD and the space industry and to recommend specific actions that we can take to mitigate those obstacles. A short summary paper of their findings and recommendations is enclosed.

I support all of these recommendations, but I want to address explicitly the second recommended action pertaining to technology support for non-NASA missions. In technology areas where we have unique facilities and expertise to offer, it will be NASA's policy to support the DOD and the space industry through cooperative R&T programs just as we do in Aeronautics. The NASA Charter clearly supports that role.

There is one area where I think we can be particularly effective in establishing closer ties with the industry in technology development and that is in the use of the Shuttle to provide access for in-space experiments. Furthermore, such activities will establish a way of doing business that leads quite naturally into use of the Space Station as a research center in space for technology and engineering experiments in zero gravity.

To begin implementing this policy, I have asked Jack Martin to increase our emphasis on in-space flight experiments; to encourage the Centers, particularly the Research Centers, to initiate cooperative R&T programs with industry in areas where industry has expressed a need and where NASA can demonstrate both its willingness and ability to help; and finally, to work with industry and DOD to select those areas for which NASA should be the national R&T leader.

I expect that there will be further discussion of this topic at the Joint Policy Review Committee/Center Director meeting on April 9.



James M. Beggs

Enclosure

Appendix C-3

STUDY OF U. S. INDUSTRY USE
OF NASA IN-SPACE FACILITIES
FOR TECHNOLOGY EXPERIMENTS

HOWARD T. WRIGHT - DEC. 1984

OBJECTIVES OF STUDY (REF. 1)

- o ASSESS THE USE OF NASA'S IN-SPACE FACILITIES BY U.S. INDUSTRY FOR TECHNOLOGY EXPERIMENTS.
- o CONSIDER PROCEDURES, PRICING POLICY, SCHEDULE, PROPRIETARY CONSIDERATIONS, LEGAL ASPECTS, ETC.
- o RECOMMEND POLICIES AND PROCEDURES THAT WOULD FACILITATE INDUSTRY'S USE OF NASA'S IN-SPACE FACILITIES - USE NASA'S CURRENT POLICY FOR INDUSTRY USE OF NASA'S WIND TUNNELS AS A MODEL.

IMPLEMENTATION

- o SOLICIT VIEWS OF OTHER CENTERS AND REPRESENTATIVES OF INDUSTRY.
- o COORDINATE WITH OTHER NASA ORGANIZATIONS RESPONSIBLE FOR SPACE COMMERCIALIZATION, SIS PRICING POLICY, OSSA, OSF, OSS, OAST, ETC.

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STUDY APPROACH

- o THE STUDY TEAM AT LANGLEY MET AND REVIEWED IN SOME DETAIL THE POLICIES AND PROCEDURES FOR INDUSTRY USE OF NASA'S WIND TUNNEL FACILITIES.
- o THE STUDY TEAM THEN PREPARED A LIST OF KNOWN IN-SPACE FACILITIES, TENTATIVE RECOMMENDATIONS, AND TOPICS FOR DISCUSSION. THESE WERE SENT TO ALL CENTER REPRESENTATIVES AND SEVERAL INDUSTRY REPRESENTATIVES AND FOLLOWED UP BY A VISIT TO OBTAIN SPECIFIC COMMENTS AND RECOMMENDATIONS.

THE STUDY TEAM WISHES TO ACKNOWLEDGE THE ENTHUSIASTIC
SUPPORT, DATA, AND SUGGESTIONS PROVIDED BY ALL CENTER, HEADQUARTERS
AND INDUSTRY REPRESENTATIVES

THE INDUSTRY REPRESENTATIVES CONTACTED WERE

McDONNELL DOUGLAS - ADRAIN O'NEAL

LOCKHEED - ROBERT HAIGHT

TRW - AL SABROFF

STUDY CONCLUSIONS

1. POLICIES AND PROCEDURES ARE NOW IN EFFECT TO FACILITATE U.S. INDUSTRIES USE OF NASA'S IN-SPACE FACILITIES. (ONCE A DECISION TO FLY AN EXPERIMENT HAS BEEN MADE) JEA, IFA, IGA, ETC.
2. THERE IS A REQUIREMENT TO ESTABLISH A PROCESS WITH APPROPRIATE CRITERIA FOR SELECTION OF EXPERIMENTS.
3. THE U.S. INDUSTRY IN GENERAL WILL NOT SUBMIT THEIR PROPOSAL TO A PEER REVIEW TO JUDGE THE MERIT OF THEIR PROPOSED EXPERIMENT AS A PART OF THE SELECTION PROCESS AND THEY WILL INSIST ON PROPRIETARY RIGHTS TO THE EXPERIMENT RESULTS. (NASA MUST BE ABLE TO PROVIDE ASSURANCE THAT THESE RIGHTS WILL BE PROTECTED.)
4. THERE IS A WIDESPREAD LACK OF KNOWLEDGE IN INDUSTRY (EVEN WITHIN THE AEROSPACE INDUSTRY COMPANIES THAT ARE WORKING WITH NASA ON A REGULAR BASIS) OF THE CURRENTLY AVAILABLE IN-SPACE FACILITIES.
5. INDUSTRY WOULD BE ENCOURAGED TO INVEST IN SPACE EXPERIMENTS IF NASA COULD SHORTEN THE LEAD TIME REQUIRED AND PROVIDE ASSURANCE THAT PROMISED FLIGHT DATES WILL BE KEPT.

RECOMMENDATIONS

1. THE NUMBER ONE UNANIMOUS RECOMMENDATION OF THE RESPONDANTS INTERVIEWED SUGGESTS THAT NASA PREPARE A DESCRIPTION OF THE IN-SPACE FACILITIES AVAILABLE AND PROVIDE FOR A WIDESPREAD DISSEMINATION OF THIS INFORMATION TO INDUSTRY.
 - o THE DESCRIPTION SHOULD BE SIMPLE, WITH PICTURES, EXAMPLES OF THEIR USE, AND A BRIEF EXPLANATION OF THEIR CAPABILITY. (BROCHURES ARE PRESENTLY AVAILABLE FOR SOME OF THE FACILITIES.)
 - o A DOCUMENT NOW IN PREPARATION AT MARSHALL AND EXPECTED TO BE AVAILABLE IN EARLY 1985 SHOULD SATISFY THE ABOVE RECOMMENDATION.
 - o THE DOCUMENT SHOULD BE DISTRIBUTED TO THE U.S. INDUSTRY ALONG WITH INSTRUCTIONS DESCRIBING HOW TO CONTACT NASA AND ALSO DESCRIBING THE SELECTION PROCESS AND CRITERIA.
 - o NASA PRESENT AT IR&D REVIEWS WITH INDUSTRY
 - o ADVERTISEMENTS IN TRADE JOURNALS (SEND FOR A DESCRIPTION OF SERVICES AVAILABLE)
 - o INDUSTRY WORKSHOP
 - o NASA PAPERS AT AIAA MEETINGS AND OTHER NATIONAL SYMPOSIA
 - o OTHER

2. ESTABLISH A SINGLE POINT OF CONTACT WITHIN NASA FOR INITIAL INDUSTRY CONTRACT.

- o THIS STUDY COMMITTEE WAS STRUGGLING WITH THIS RECOMMENDATION EARLY IN THE STUDY HOWEVER ON OCTOBER 29 THE NASA ADMINISTRATOR ISSUED THE NASA COMMERCIAL USE OF SPACE POLICY DOCUMENT (REF. 2) WHICH IDENTIFIED AN ORGANIZATIONAL INITIATIVE TO ESTABLISH COMMERCIALIZATION OFFICES AT HEADQUARTERS AND FIELD CENTERS. THE NASA ADMINISTRATOR ALSO ISSUED NM 1 1103.3A (REF. 3) DESCRIBING THE RESPONSIBILITIES OF THE NEW HEADQUARTERS ORGANIZATION. THESE DOCUMENTS INDICATE THAT ALL INDUSTRY PROPOSALS FOR TECHNOLOGY EXPERIMENTS ENTER THE NASA SYSTEM THROUGH THE HEADQUARTERS OFFICE OF COMMERCIAL PROGRAMS.

3. ESTABLISH A SELECTION PROCESS AND CRITERIA FOR INDUSTRY PROPOSALS.

IN GENERAL MOST OF THE COMMENTS RECEIVED ON THIS SUBJECT SUGGEST A SIMPLE, SUBJECTIVE PROCESS BASED ON THE FOLLOWING GENERAL GUIDELINES.

- o PROPOSALS SHOULD BE GIVEN CONSIDERATION ON A FIRST COME FIRST SERVED BASIS
- o PROPOSALS THAT ARE FRIVOLOUS AND/OR NOT IN CONSONANCE WITH PRUDENT USE OF GOVERNMENT FACILITIES WILL BE REJECTED.

RECOMMENDATIONS CONCLUDED

- o THE GOVERNMENT WILL NOT ATTEMPT TO EVALUATE THE FEASIBILITY OF THE PROPOSED EXPERIMENT.
- o THE CAPABILITY OF THE SHUTTLE AND THE AVAILABILITY OF THE VARIOUS FACILITIES MAY LIMIT THE NUMBER OF PROPOSALS THAT CAN BE ACCOMMODATED.
- o INDUSTRY SHOULD BE ADVISED AS TO THE AVAILABILITY OF NASA'S IN-SPACE FACILITIES UPON INITIAL CONTACT SO THAT THEY MAY CONSIDER ALTERNATIVES MOST SUITABLE TO THEIR SCHEDULE DESIRES.

SPACELAB - LONG WAIT (3 YRS.)

MID-DECK - SIMPLE EXPERIMENT NOW BOOKED FOR 2 YEARS

HITCHIKER - SHORT WAIT

GAS - SHORT WAIT

ETC.

- 4. NASA SHOULD CONSIDER INDUSTRIES USE OF SELECTED GROUND BASED FACILITIES TO ASSIST IN THE DEVELOPMENT OF FLIGHT PAYLOADS. (SHORT TIME ZERO G DROP FACILITIES, ALTITUDE AND ENVIRONMENTAL FACILITIES ETC.)

POTENTIAL CHALLENGES

1. SINCE IT IS NOT POSSIBLE TO PREDICT THE VOLUME OF INDUSTRY RESPONSE TO THE OFFER TO USE NASA'S SPACE FACILITIES, CARE MUST BE TAKEN TO LIMIT PROMISES FOR FLIGHT OPPORTUNITIES TO THE STS CAPABILITY. THERE WERE NUMEROUS EXPRESSIONS OF CONCERN WITHIN NASA, THAT LONG LEAD TIMES AND SCHEDULE SLIPS COULD ADVERSELY AFFECT OUR INDUSTRY RELATIONSHIPS. ALL RESPONDANTS DID AGREE THAT THE SITUATION IS IMPROVING AND THAT AS THE STS BECOMES FULLY OPERATIONAL THE PROBLEM WILL DIMINISH.
2. THIS STUDY ASSUMED THAT NO MODIFICATIONS WOULD BE MADE TO THE NASA FACILITIES TO ACCOMMODATE AN EXPERIMENT, AND THAT THE IMPACT ON THE SHUTTLE WOULD BE MINIMAL. (CREW TRAINING, SHUTTLE ATTITUDE, TEST TIMELINE, ETC.). THESE ASSUMPTIONS COULD ELIMINATE FROM CONSIDERATION SOME VERY SIGNIFICANT EXPERIMENTS WITH HIGH COMMERCIAL APPLICATION. THERE IS A STRONG POTENTIAL FOR INDUSTRY EXPERIMENTS THAT ARE LARGE, EXPENSIVE, AND WOULD INVOLVE A SIGNIFICANT AMOUNT OF MISSION TIMELINE, CREW TRAINING, INTEGRATION COST, ETC. SEVERAL EXAMPLES OF SUCH EXPERIMENTS WERE RECENTLY DISCUSSED AT A LARGE SPACE ANTENNA CONFERENCE AT LANGLEY. SINCE THIS CLASS OF EXPERIMENT COULD IMPOSE A SIGNIFICANT IMPACT ON NASA RESOURCES, CONSIDERATION SHOULD BE GIVEN TO THE PROMOTION OF JEA'S BETWEEN INDUSTRY AND OAST TO PERMIT INDUSTRY TO INVEST IN THE TEST ARTICLES AND NASA TO PROVIDE THE FLIGHT OPPORTUNITY AND GAIN THE BENEFIT OF FLIGHT EXPERIENCE WITH LARGE STRUCTURAL DEVICES.

APPENDIX D

Background on the Space and Earth Science
Advisory Committee (SESAC) Task Force on
Scientific Uses of the Space Station

- NASA's Office of Space Science and Applications has established an advisory committee on space station.
- The committee is created under the auspices of an already existing advisory committee: The Space and Earth Science Advisory Committee.
- This new committee is called "The SESAC Task Force on Scientific Uses of the Space Station."
- It is chaired by Peter M. Banks, Professor of Electrical Engineering and Director of Space, Telecommunications and Radioscience Laboratory (STARLAB) at Stanford University.
- The Banks committee has four important tasks:
 - assist NASA in planning the scientific utility of the station,
 - act as focal point for scientific input into space station activities,
 - aid in understanding relationship between new capabilities and the existing science and applications program, and
 - periodically update scientific requirements.
- The committee consists of about 20 U.S. scientists and several international observers.

The report of SESAC Task Force meeting from August 13-17, 1984:

"The Task Force on Scientific Uses of Space Station (TFSUSS) is organized under the NASA Advisory Council as a sub-group of the Space and Earth Science Advisory Committee (SESAC). The responsibilities of the Task Force include, among others providing NASA with assistance in planning for the scientific utility of Space Station, helping NASA to define the relationship between Space Station and the existing program of space research, and acting as a focal point for the general interests of the national research community in developments relating to Space Station."

END

DATE

NOV. 5, 1985